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TRANSATLANTIC RADIO RECEPTION.*

BY

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INTRODUCTION.

WITH the opening of hostilities between the United States and the Central Powers, there arose the physical possibility that the enemy would interrupt the Transatlantic cables. In order to provide for such a contingency, it therefore became necessary to take steps to improve the then existing Transatlantic radio service.

Some time before the United States entered the war the United States Government, through the Navy Department, in the interests of neutrality assumed control of the Transatlantic radio transmitting stations at Sayville, Long Island, and Tuckerton, N .J., these stations having been owned and controlled by German interests.

On October 4, 1917, a conference between representatives of the Navy and War Departments was held at New London, Connecticut "relative to the substitution of radio for cable service in the Atlantic." At this conference a plan was formulated to initiate a system of Transatlantic radio communication "to serve in event of failure of cables between the United States and Europe as brought to attention by the Interallied Protocol, 22, August."

* Communicated by Maj.-Gen. George O. Squier, Chief Signal Officer, U. S. Army.

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The diagrams shown as exhibit A1, A2 and A3 indicate the general plan of operation decided upon. The transmitting stations at Annapolis, Md., and Marion, Mass., were not at that time completed. Later, New London was abandoned by the Navy Department as a control receiving centre in favor of Belmar, New Jersey. Receiving stations were also established by the Navy at Chatham, Mass., and Bar Harbor, Maine. Washington was not used to any extent for receiving Transatlantic traffic.

Subparagraph 2 of paragraph "F" of the New London Protocol of October 4, 1917, reads as follows:

> "With respect to the three American receiving centers herein recommended, it will be noted that these centers are subject to change if and when better locations are known. In harmony with the suggestion at the end of Paragraph A in the Protocol, plans are now making for the establishment of experimental receiving centers in widely different localities in North America, and perhaps in the West Indies and elsewhere. Therefore, our future course with reference to the number and location of receiving centers will depend upon the result of these proposed experiments."

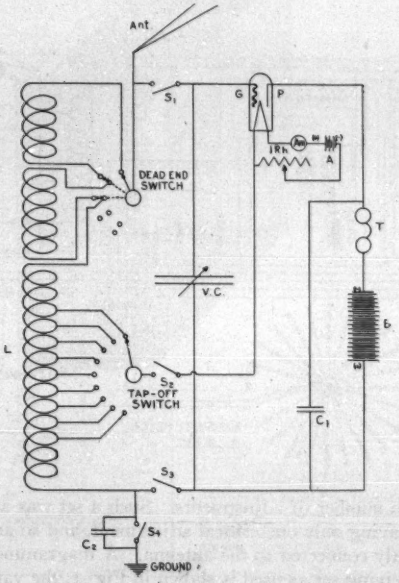
The above paragraph refers to the proposed joint Army and Navy program for the determination of the most favorable receiving centres. Owing to the fact that Army posts were located at numerous points widely separated throughout the United States, it was obviously practicable for the Signal Corps to take up the matter of determining optimum Transatlantic receiving centres.

It was believed that it would be possible to find several sites so located that, at any given hour of the day, at least one of the stations would be able to make perfect copy, and that by combining the results secured at several stations, an uninterrupted receiving service could be secured. It was appreciated that the British Association Committee for Radiotelegraphic Investigation had collected and analyzed a large amount of data bearing on X's,[1] and also that De Groot had conducted an extensive investigation in the Dutch East Indies bearing on this matter, but it was felt that the problem confronting American radio engineers and scientists was, from the nature of the case, more or less local in character and peculiar to Transatlantic reception on this continent.

[1] The symbol X will be used throughout this report to indicate any extraneous electrical disturbances, except interference from other radio stations and inductive effects from power lines, and which tend to interfere with radio communication. The terminology will thus be made to conform with the practice of the British Association.

On October 15, 1917, the writer was detailed by the Officer-in-Charge of the Radio Development Section to organize the work of securing the necessary data upon which a decision might be based with reference to such optimum receiving centres. First Lieut. Eugene Sibley was detailed to assist the writer in the organization of the work.

FIG. 1.



CONDITIONS AND EQUIPMENT.

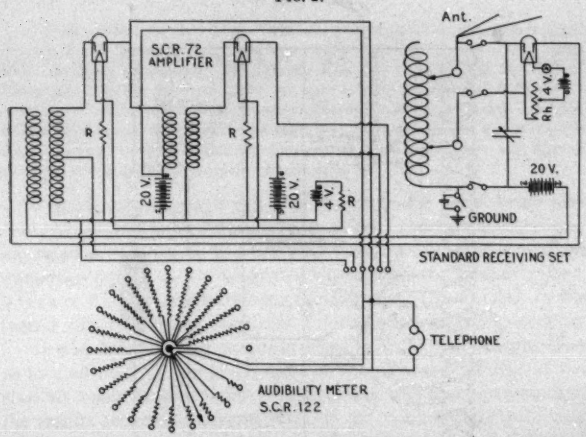
It was decided to begin the investigation by establishing six experimental Transatlantic receiving stations at suitably located Army posts, with headquarters at Washington, D. C., and steps were immediately taken to secure the necessary personnel and equipment.

The general plan of procedure included not only the taking

of audibility measurements on static X intensity and received signal strength during twenty-four hours daily, but, in addition, arrangements were made to secure at all stations simultaneous meteorological records, the purpose being not only to locate optimum receiving centres but, if possible, to determine the factors which govern extraneous electrical disturbances.

Owing to the personal equation of the operators, it was obviously essential that a receiving set should be employed having

FIG. 2.

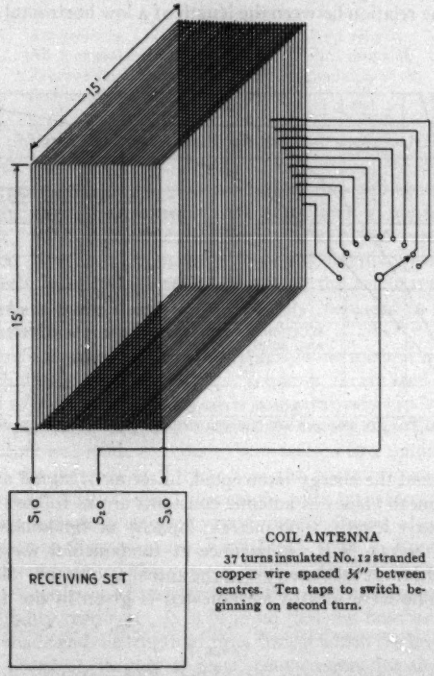


a minimum number of adjustments. Such a set was accordingly designed having only one critical adjustment, and so arranged as to be directly connected to the antenna. A diagrammatic sketch of this receiving set as used is shown in Fig. 1, the variable condenser (0.003 M.F.) being the adjustable element just referred to. The total inductance in the antenna circuit had a value of approximately 14.4 M.H. Standard Signal Corps V.T-1 detector tubes, 20-volt "B" batteries, and telephone receivers were employed. Standard amplifiers, SCR-72, were used in connection with these receiving sets. The shunted telephone method of measuring the audibility of signal strength and X intensity was used. For this purpose, audibility metres made by the General Radio

Company, and reading from unity to 8000, were employed. The complete scheme of connections is shown diagrammatically in Fig. 2.

The antenna system employed in the tests consisted of two horizontal wires, each 1000 feet long (304.8 metres), arranged

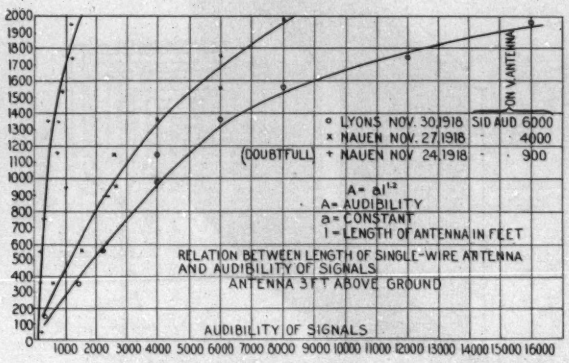
FIG. 3.



in the form of a "V," the two wires being separated by an angle of 10° and supported on suitable insulators 15 feet (4.6 metres) above the ground. This particular height was used for physical reasons, as in certain cases it was necessary to extend the antenna across roadways, this being the lowest practical height under such circumstances. The median line between the two wires of the

antenna coincided with the great circle joining Lyons, France, and a given receiving station. The antenna wires were placed at an angle with respect to one another in order to partially compensate for any slight error in the determination of the true direction of the great circle. As an example of the functioning of an antenna of the general type used in these tests there is shown in Fig. 4 the relation between the length of a low horizontal one-wire

FIG. 4.



antenna and the energy intercepted, in terms of signal audibility.

The mean values of antenna constants are as follows: Fundamental wave length, 1609 metres; capacity at fundamental wave length, 0.00355 M.F.; inductance at fundamental wave length, 0.2026 M.H. A tabulated list of the antenna constants taken when the stations were located as indicated is given in the following table:

TABLE I.

Antenna Constants, Special Radio Receiving Stations.

	Madison	Oberlin	Ithaca	Orono	Rockport	Princeton	Ashland
Wave length (metres)	1620	1520	1735	1594	1610	1515	1670
Capacity (MF)	0.003428	0.002982	0.003905	0.003078	0.003322	0.002919	0.003623
Inductance (MH)	0.2032	0.2039	0.2044	0.2038	0.2064	0.1938	0.2048

Through the coöperation of the Meteorological Section of the Science and Research Division, a meteorological observer and suitable meteorological equipment were secured for use at the several stations. The following meteorological observations were made, continuous automatic records being secured of the first four factors listed below.

Air pressure	Wind velocity
Air temperature	Wind direction
Relative humidity	Condition of sky
Soil temperature	

Hourly observations were made on the last three variables mentioned above.

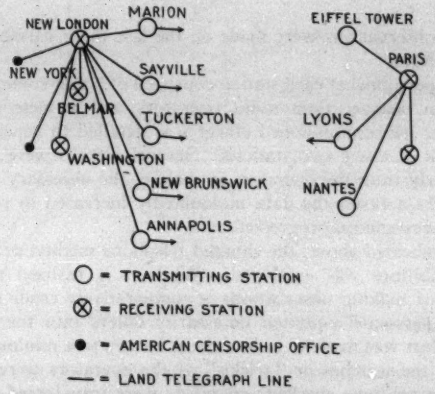
The personnel at each station consisted of a non-commissioned officer in charge, four radio operators and a meteorological observer. A commissioned officer was detailed to supervise the operation of every two stations. Several months were required to properly train the operators in making the necessary observations. As a result the data undoubtedly increased in reliability as the investigation progressed.

As indicated above, the shunted telephone method of measuring audibilities was employed. While it is realized that this method of making observations is comparatively crude and that a large personnel equation necessarily enters into the records, every effort was made to reduce these factors to a minimum. To this end the watches or "tricks" of the operators were rotated and their readings checked; operators were transferred at times from one station to another; receiving sets were also changed. In addition to these measures First Lieut. John A. Riner acted as inspector and visited the various stations from time to time for the express purpose of standardizing the observations, particularly the audibility readings. It is believed that the number of observations made and the length of time during which the investigation was in progress, in part at least, compensates for the inherent inaccuracy of the individual observations.

In determining the relative merits of the various receiving centres, the values of the X-signal ratios are of some value. However, in the last analysis the utility of a given station site was determined by the character of the results in the form of actual copy taken. The Transatlantic traffic from the European stations

at Lyons, France (YN); Rome, Italy (IDO); Nantes, France (UA); Carnarvon, Wales (CV), and to some extent Nauen, Germany (POZ), was copied daily and the copy forwarded to the Washington office. Beginning April 1st this copy was carefully compared by an office force trained for the purpose and a daily rating given to each station. By comparison of these results it was possible to determine the net results of the varying receiving conditions on actual traffic. This method disclosed facts which

EXHIBIT A1.



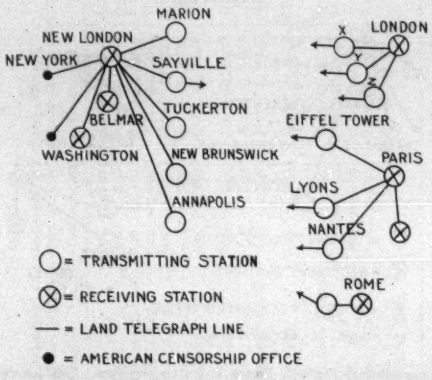
America transmitting. France receiving. Paris designated as chief receiving centre and Lyons designated to send acknowledgments.

would not have been apparent from an examintaion of the numerical readings on signals and X's alone.

A complete list of the various station sites is shown in Table II following, the first six in the list being the first locations investigated. Not more than seven stations were actually making observations under standard conditions at any one time. In selecting the first six sites for investigation it was realized that the Southern locations at Ft. Screven, Ga., and Ft. Brown, Texas, would be unsuitable during the summer months, but it was desired to study the X "Static" conditions at these points. The inland stations were selected with a view not only to studying the relative

X effects but also to note any possible absorption, reflection, or refraction phenomena connected with the signals received from European stations. As soon as it became evident that a given station site was, for any reason, wholly unsatisfactory for Transatlantic reception it was abandoned and the equipment and personnel moved to a new location. If good results were secured at a new site, employing the same equipment and personnel that could not secure such results at a former site, the evidence was

EXHIBIT A2.



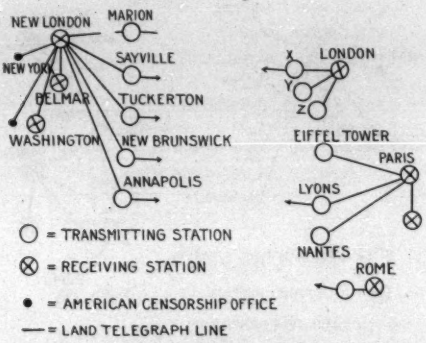
England, France and Italy transmitting. America receiving. New London designated as chief receiving centre and Sayville designated to send acknowledgments.

reasonably conclusive as to the relative merits of the sites investigated.

In securing the data, hourly readings on X audibility and half hourly readings on signal audibility were made. Each station was equipped with a high grade timepiece which was carefully regulated and set to keep standard time. The X intensity readings were made with the receiving apparatus set to respond to an 8000-metre wave and also to a 14,000-metre wave. The lower value was taken for the reason that it was of the order of the shortest wave used in long distance work and the higher value was of the order of the longest waves in use. X audibility readings

were made when using the detector, one step, and two steps amplification. Signal audibilities were read on one step amplification only. In making the audibility measurements on X's the practice was followed of adjusting the audibility metre until near the point of extinction of sound due to the individual crashes, and if no sound was heard for a period of approximately three seconds the setting of the metre was taken as the reading. After some experience the operators were able to make fairly comparable readings. Owing to the high value of the X intensity during the

EXHIBIT A3.



America transmitting, England, France and Italy receiving. Chief receiving centres: England, London; France, Paris; Italy, Rome. Stations sending acknowledgments: England, ——; France, Lyons; Italy, Rome.

summer months, and because the audibility metres did indicate values above 8000, the X intensity readings on the detector only, were plotted subsequently to July 1st. All data considered in this report were collected in the year 1918.

The daily numerical radio and meteorological data were forwarded to the Washington office and reduced to the form of curves and charts. The curves were so arranged that at any given hour of the day simultaneous conditions at all of the stations could be noted. The data in this form were subjected to careful analysis with the results hereinafter outlined. In passing, it may be of interest to note that more than 1500 separate observations were plotted for each day's record, ten distinct lines of evidence being

TABLE II.

List of Experimental Transatlantic Receiving Stations.

Stations	Location	Date opened	Date closed	Reasons for closing
Fort Monroe	Virginia	Dec. 14, 1917	April 25, 1918	Local radio interference.
Camp Devens	Ayer, Mass.	Jan. 1, 1918	May 29, 1918	Local radio interference.
Fort Screven	Near Savannah, Ga.	Jan. 4, 1918	May 19, 1918	High static (X's).
Fort Brown	Brownsville, Tex.	Jan. 16, 1918	April 24, 1918	High static. Very weak signals.
Fort Leavenworth	Kansas.	Jan. 2, 1918	April 2, 1918	High static. Weak signals.
Fort Snelling	Minnesota.	Jan. 26, 1918	June 3, 1918	High static. Weak signals.
University of Maine	Orono, Maine.	Jan. 27, 1918	Oct. 15, 1918	Radio survey showed better static signal ratio at Van Buren.
Oberlin College	Oberlin, Ohio	Feb. 25, 1918	Nov. 26, 1918	Investigation discontinued.
University of Michigan	Ann Arbor, Mich.	May 11, 1918	Aug. 5, 1918	High static. Very weak signals.
Ashland	Near Richmond, Va.	May 11, 1918	Nov. 2, 1918	Unfavorable static signal ratio after July 1.
University of Wisconsin	Madison, Wis.	June 9, 1918	Nov. 3, 1918	High static and weak signals from Lyons and Carnarvon.
Rockport	On Cape Ann, Mass.	June 16, 1918	Nov. 26, 1918	Investigation discontinued.
Princeton University	Princeton, N. J.	June 18, 1918	Nov. 26, 1918	Investigation discontinued.
Cornell University	Ithaca, N. Y.	June 20, 1918	Nov. 26, 1918	Investigation discontinued.
St. Mary's College	Van Buren, Maine.	Nov. 3, 1918	Nov. 26, 1918	Investigation discontinued.
Sault St. Marie	Michigan.	*		
Maryland State Agricultural College	College Park, Md.	*		

* NOTE.—Stations at these sites were installed but were not put into commission owing to investigation being discontinued.

recorded for each station. The curve sheets were thirty inches wide and totalled 270 feet in length. The reduced photostat copies are more or less unsatisfactory, as the original curves were plotted on a larger scale and in colors, therefore it has been considered inadvisable to include them in this article. The original curves and data are on file in the office of the Chief Signal Officer, the curves and charts being packed in a box marked STARS (meaning Special Transatlantic Receiving Stations), Case No. 1, and the data and copy sheets in a box labelled STARS, Case No. 2.

COMPARISON OF X INTENSITY WITH VARIOUS METEOROLOGICAL FACTORS.

Following is a record of the comparisons made between the meteorological factors and X intensity:

In the majority of cases the value of X intensity or audibility, 50 per cent. above the mean weekly or monthly value and 50 per cent. below the same mean, was considered high and low X intensity respectively. In one or two cases, double the mean value was used as a high X value. The 50 per cent. values just referred to are probably more nearly rational than the 100 per cent. value, and are based on a consideration of the ratio between the audibility of the X's and signal strength encountered in practice. It was found that if the X/S ratio became equal to three, the copy began to be imperfect and higher values at this ratio gave increasingly broken copy. The character of X disturbances is, of course, an important factor, but unfortunately cannot be given numerical representation. The 50 per cent. increase of X audibility over the mean value for a given period usually resulted in a ratio of X/S of at least 3 and hence is believed to be a fairly satisfactory basis for comparison purposes.

In compiling the tables which follow the X audibility on the 14,000-metre wave was used, unless otherwise noted. In those cases in which the X intensity and the value of the meteorological factor under investigation were both high or both low at a given time, with respect to a specified norm they were considered to be opposite departures. The numbers in the tables indicate the number of occurrences or counts under the conditions specified.

In the comparisons which follow, certain stations were selected during certain periods, because of the fact that various circumstances connected with the operation of the stations gave evidence that the data during that particular period and at that special place

was best adapted to the particular factors being studied. The moving of the stations from time to time to new sites also necessarily limited availability of data during a certain period.

BAROMETRIC PRESSURE.

In considering the possible effect of barometric pressure on the presence and intensity of X's, the records of the three stations—Ithaca, N. Y., Devens, Mass., and Monroe, Va.—were examined over a period of several months. In the case of the two stations first mentioned, the mean X audibility and barometric pressure for the entire period was used as a basis. In the case of Monroe, the weekly mean value of X audibility and the monthly mean value of the barometric pressure were used. In making this comparison,

TABLE III.

Comparison Between Extreme Values of Audibility of X's and Barometric Pressure.

	Camp Devens, Mass. Apr. 1 to May 28	Fort Monroe, Va. Mar. 4 to Apr. 20	Ithaca, N.Y. July 15 to Sept. 1
Similar departures from mean values	194	159	49
Opposite departures from mean values	303	140	25
When barometric pressure was at mean value audibility of X's was low	460	201	343
When barometric pressure was at mean value audibility of X's was low	297	129	177

cases of marked departures in X audibility were noted and the corresponding barometric conditions investigated. Fifty per cent. above the mean and 50 per cent. below the mean X audibility were considered high and low values respectively. The mean barometric pressure plus .2 inches (5 mm.) was considered high barometric pressure, and the mean pressure less .2 inches as low barometric pressure. A preliminary series of comparisons was made, using different ranges of barometric pressure, and it was found that the limits just mentioned were the most rational. Table III embodies the results of the comparisons above outlined.

It will be noted from the examination of Table III that there appears to be no particular agreement between X audibility and barometric pressure, with the possible exception that there were more cases in which the X audibility was low than those in which the barometric pressure was at the mean value.

Another comparison between barometric conditions and the interference due to extraneous electrical disturbances was based on the grade of the copy obtained at the several special receiving stations. It is noted elsewhere that the daily copy received at the several stations was carefully read, compared, and a relative grade given to the same, due regard being given to the individual ability of the various operators. The copy taken at Orono, Maine, Rockport, Mass., Ithaca, N. Y., and Ashland, Va., between June 1 and November 15 served as a basis for this comparison. The meteorological condition with respect to barometric pressures and precipitation, as indicated on the United States daily weather

TABLE IV

Comparison of Grade of Copy and General Barometric Conditions.

	Orono		Rockport		Cornell		Ashland		Totals	
	Good	Bad	Good	Bad	Good	Bad	Good	Bad	Good	Bad
High pressure area	5	9	5	10	7	3	8	9	25	31
Low pressure area	2	4	2	2	1	2	3	3	8	11
Normal pressure	7	6	10	10	9	15	7	11	33	42
High pressure area accompanied by precipitation	2	3	2	2	3	4	3	2	10	11
Low pressure area accompanied by precipitation	11	11	3	13	7	10	2	6	23	40
Normal pressure accompanied by precipitation	2	10	5	6	5	8	6	11	18	35
High pressure area approaching	2	3	1	2	0	1	2	0	5	6
Low pressure area approaching	0	0	1	1	0	3	0	4	1	8

map for the day on which the copy was decidedly good or decidedly bad was noted. Table IV sets forth in condensed form the results of this comparison.

An examination of the number of instances at each station and also the totals appears to indicate that there is no agreement between barometric pressure and the interfering character of the X's. In addition to the above comparison, note was also made of the barometric condition over the ocean off the coast of Newfoundland. This comparison is shown in Table V.

It may be noted that in the majority of cases a condition of general X interference resulting in poor copy obtained at all stations when a high pressure area existed off the Newfoundland Coast, and that in the greater number of cases good copy was

received at all stations when a low pressure area existed off the Newfoundland Coast. As the majority of storm centres which travel over the eastern United States pass out to sea in the general region of the north Atlantic Coast, it would appear from the figures there may be some general relation existing between general barometric conditions over the eastern part of the United States and the attendant atmospheric electrical conditions which result in more or less interference to radio traffic. The details, however, of this relation, if indeed one exists, are not evident.

WIND DIRECTION.

A preliminary examination of the data from the station at Camp Devens with reference to any possible relation which might exist between the direction of the wind and the intensity of the

TABLE V.

Barometric Condition on Ocean off Newfoundland Coast.

	Good copy at all stations	Poor copy at all stations
High pressure area	8	23
Low pressure area	16	11
Normal pressure area	8	12

extraneous electrical disturbances, did not show any clear relation between these two factors for that particular station.

A similar examination of the data secured at the Fort Brown Station for a period extending from March 7 to April 24 also does not show any particular relation between the direction of the wind and the X audibility. A more or less complete examination of the wind direction data for all stations is set forth in Table VI.

An examination of this table would appear to indicate that, in general, the X audibility does not bear a definite relation to the direction of the wind. It will be noted that in those cases in which the X intensity was high, and also in those in which it was low, the greatest number of counts for wind direction fall opposite southwest, northwest and northeast. The results at the particular stations were not identical, differing somewhat from the general results.

A comparison was made between the wind velocity and the X audibility on an 8000-metre wave for the month of May at the station at Camp Devens. By inspection it was found that there

were 7 similar radical departures from the mean values and 13 opposite departures. In 18 cases when the wind velocity was at the mean value, X audibility was low, and only 1 case when it was high. For this particular place, the figures would appear to indicate that when the wind velocity had a mean value or above, the X intensity was low. In this connection, it should be noted that in the majority of cases examined at this station, the highest point of the wind velocity occurred an hour or possibly two after the lowest point of X audibility.

A comparison similar to the above was made of the data secured at the Fort Brown Station for a period between March 7 and April 24, radical departures from the mean value of the X intensity on an 8000-metre wave being noted by inspection. Sixty-three cases were examined. There were 10 similar departures from the mean values and 10 opposite departures. In 10 cases when the wind was at the mean value, the static was low, and in 15 cases, high. The results at this Station appear to fall into line with those at the Devens Station. An examination of the Fort Brown data for March 1 to April 24 for 14,000-metre wave setting was also made. In this comparison, all those cases in which the X intensity had the value of 8000 or where it dropped to 350 audibility or below, were noted. The mean velocity of the wind during this period was 8.4 miles per hour. A total of 298 cases were examined, in 248 of which the X intensity had a value of at least 8000, and in 50 of which it had a value of 350 or below. Of these cases, there were 42 similar departures from the mean and 66 opposite departures. Thus, it is seen that the data examined on the above indicated basis points to the same general conclusion as previously noted.

A more comprehensive examination of the wind velocity data at all of the Stations was also made. In this investigation, not only simultaneous radical changes of X intensity and wind velocity were considered, but also those cases were noted in which the highest or lowest point of a change in wind velocity occurred within a period not to exceed two hours of a radical X intensity change. The mean monthly wind velocity was used, except for March. Results of this examination are set forth in Table VII.

An examination of the data set forth above likewise points to the conclusion that X audibility tends to vary inversely as the wind velocity, there being 213 opposite departures from the mean compared with 145 similar departures.

TABLE VI.

X Audibility Versus Wind Direction.

	Devens	Rockport	Monroe	Ashland	Scriven	Princeton	Snelling	Cornell	Leavenworth	Madison	Brown	Totals
	Mar. 4 to May 29	June 17 to Aug. 1	Mar. 4 to Apr. 26	May 22 to Aug. 1	Mar. 5 to May 19	June 18 to Aug. 1	Mar. 9 to May 30	June 20 to Aug. 1	Mar. 7 to Apr. 3	June 11 to Aug. 1	Mar. 7 to Apr. 24	
When audibility was low, wind was in N	3	2	12	2	2	1	7	3	1	1	2	36
NE	17	2	4	3	4	1	3	1	2	1	7	41
E	5	1	7	1	8	3	7	0	1	2	1	36
SE	2	1	1	0	1	0	3	5	0	2	12	27
S	3	2	7	6	4	1	5	4	1	7	5	45
SW	19	6	12	11	9	1	5	6	8	5	6	88
W	12	1	3	7	2	0	4	3	0	6	0	38
NW	8	5	4	14	1	1	8	9	2	2	2	56
Calm	0	0	0	13	0	0	1	0	0	0	0	14
When audibility was high, wind was in N	5	1	6	2	1	1	7	1	3	4	1	32
NE	8	6	1	7	5	1	9	4	0	0	3	44
E	6	0	5	3	3	1	5	4	0	2	1	30
SE	3	0	4	10	4	0	6	2	0	2	12	43
	4	0	6	0	3	3	6	2	0	4	8	36
SW	14	0	15	16	9	3	8	2	4	5	3	79
W	12	1	3	4	2	0	4	3	1	2	0	32
NW	8	0	6	5	5	0	11	9	2	1	0	47
Calm	0	0	0	9	0	1	0	0	0	0	0	10

AIR TEMPERATURE.

The possible relation of air temperature to extraneous electrical disturbances was investigated for all stations covering a period from March 1 to August 1, 1918. In this comparison monthly mean temperature values and weekly X audibility values were used as a basis. Double the mean weekly value of X audibility was considered high and half the mean value as low. Six degrees above the mean temperature value and six degrees below were considered high and low temperature values respectively. Table VIII shows the number of cases of decidedly high or low values of X audibility as they occur in order from day to day, together with corresponding air temperature conditions.

From the table it will be noted that, in the majority of cases, at the time the air temperature stands at the mean value or above the mean value the X audibility is low. It is evident that this relation does not hold at all stations listed, as, for example, at Rockport and Princeton.

SOIL TEMPERATURE.

A preliminary comparison of the soil temperature (25 C.M. beneath the surface of the earth) and the X audibility data secured at Ashland, Devens and Brown did not yield concordant results. The changes in soil temperature were found to take place too slowly to account for the frequent marked changes in X intensity. However, this factor should be studied further, particularly with reference to signal strength.

SKY CONDITIONS.

It is frequently reported by radio operators that they can forecast or predict the possibility of unusually heavy X disturbances by observing the condition of the sky, particularly with reference to the character of the clouds. In order to check this more or less popular opinion, an examination was made of the sky conditions at several of the Transatlantic receiving stations in connection with existing X disturbances.

The following table sets forth the results of the observations at Fort Brown covering a period from March 18 to April 24.

A more complete examination of the data with reference to sky conditions was made in connection with the operation of the sta-

TABLE VII.

X Audibility Versus Wind Velocity.

	Devens	Rockport	Monroe	Ashland	Scriven	Princeton	Snelling	Cornell	Leavenworth	Madison	Brown	Totals
	Mar. 4 to May 29	June 17 to Aug. 1	Mar. 4 to Apr. 26	May 22 to Aug. 1	Mar. 5 to May 19	June 18 to Aug. 1	Mar. 9 to May 30	June 20 to Aug. 1	Mar. 7 to Apr. 3	June 11 to Aug. 1	Mar. 7 to Apr. 24	
Similar departures from mean values.....	23	7	23	2	10	7	18	8	7	6	10	145
Opposite departures from mean values.....	33	6	29	25	19	5	38	22	8	9	19	213
When the wind velocity was at mean value, X audibility was low....	36	10	22	28	16	3	19	15	4	16	19	188
When the wind velocity was at mean value, X audibility was high....	37	5	23	35	18	4	24	12	6	15	15	196

TABLE VIII.

Table Showing Comparison Between Extreme Values of Audibility of X's and Air Temperature.

	Camp Devens, Ayer, Mass. Mar. 4 to May 29	Rockport, Mass. June 17 to Aug. 1	Fort Monroe, Va. Mar. 4 to Apr. 22	Ashland, Va. May 13 to Aug. 1	Port Scriven, Georgia. Mar. 4 to May 7	Princeton, N. J. June 20 to Aug. 1	Fort Snelling, Minn. Mar. 4 to June 3	Ithaca, N. Y. June 20 to Aug. 1	Fort Leavenworth, Kans. Mar. 4 to Apr. 3	Madison, Wis. June 29 to July 21	Fort Brown, Texas. Mar. 4 to Apr. 25	Oberlin, Ohio. July 6 to Aug. 1	Totals
Similar departure from mean values.....	167	26	152	220	50	42	229	80	57	73	46	38	1181
Opposite departture from mean values.....	255	7	150	267	66	24	353	122	96	71	160	70	1641
When temperature was at mean value audibility of X's was low.....	187	29	125	264	147	37	222	131	21	92	207	67	1528
When temperature was at mean value audibility of X's was high.....	65	0	60	125	18	11	86	34	5	22	76	27	529

tions at Ithaca, New York, and Princeton, N. J., covering the months of August, September and October. In making this examination, the normal hours of maximum and minimum X audibility were first determined. Whenever the maximum or minimum X audibility did not occur at these hours, it was considered abnormal. Fifty per cent. above the mean value was considered high, and 50 per cent. below the mean value, low.

It is evident from the foregoing data that, at least, on the basis underlying this comparison, no definite relation can be found

TABLE IX.
X Audibility Versus Sky Conditions.

Sky condition	Low audibility	High audibility
Blue sky	13 times	59 times
Partly cloudy	12 times	25 times
Full cloudy	25 times	164 times

to exist between the condition of the sky and abnormal X audibility values.

In order to further investigate the possible effect of the sky condition on extraneous electrical disturbances, a comparison was made between the condition of the sky and the grade of copy received at the stations located at Orono, Rockport, Ithaca, and Ashland, covering the months of August, September and October. Only the records for such days were examined which showed distinctly good or poor copy, the general cloud effects and tendencies to become clearer or more cloudy being noted. The results of this examination are recorded in Table X.

TABLE X.
Table Showing Comparison of Grade of Copy and Sky Condition.

Condition of sky	Orono		Rockport		Ithaca		Ashland		Totals	
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
Blue sky	1	2	3	7	5	4	1	4	10	17
Clouds becoming lighter	9	5	10	8	8	10	10	9	37	32
Cumulus clouds	2	5	1	0	4	6	2	1	9	12
Clear changing to dense clouds	6	8	6	7	1	6	8	6	21	27
Clear changing to rain	1	0	1	4	0	1	2	5	4	10
Rain, dense clouds	7	13	1	8	5	11	5	11	18	43
Rain, becoming clear	1	1	3	5	2	2	0	0	6	8

It is also evident from an examination of the foregoing data that no definite relation appears to obtain between the condition of the sky and intensity of extraneous disturbances as indicated by the grade of copy obtainable, the exception, however, being noted that rain accompanied by thunder and lightning usually resulted in poor copy.

ABSOLUTE HUMIDITY.

A careful study was made of the absolute humidity and its possible relation to extraneous disturbances at the Station in Massachusetts from March 18 to July 1. From the daily meteorological data collected at these stations, the absolute humidity was computed and a curve of the same plotted. A comparison of this curve with the static audibility curve showed 133 similar departures from the mean values and 100 opposite departures.

A second comparison was made of the X audibility and absolute humidity at the above-mentioned station on the basis of similar and dissimilar changes in the respective curves.

On this basis it was found that there were 275 similar cases and 309 opposite changes.

A study was also made of the absolute humidity data resulting from the observations at the Station at Ithaca, N. Y. In comparing the absolute and X curves, a mean weekly value of the X audibility was used, 50 per cent. above and 50 per cent. below this mean being considered high and low respectively. The mean monthly value of the absolute humidity plus and minus one grain was used as high and low humidity respectively.

This comparison yielded the following results:

Similar departures from mean values	126
Opposite departures from mean values	148
Absolute humidity was at mean value when static was low	162
Absolute humidity was at average value when X audibility was high	107

From an examination of the results of the above comparisons, it would appear that there is little relation between absolute humidity and X intensity.

RELATIVE HUMIDITY VERSUS X AUDIBILITY.

Though the investigation with reference to absolute humidity was more or less indecisive, an examination of the relative humidity records resulting from the operation of the several stations yields a relation which is interesting and possibly significant.

In making this comparison, the fifty-fifty X intensity limits, and the mean monthly value of relative humidity, plus or minus 10 per cent., was taken as a basis of comparison. Table XI shows the results of this comparison.

At all of the 12 stations examined, with the exception of Princeton and Rockport, the X intensity and relative humidity show a marked tendency to vary together. This is also apparent from the totals, which show a large excess of similar departures from the mean values. With reference to Princeton and Rockport, the values of both relative humidity and X intensity were very high, so high in fact, that owing to the limits of the audibility metre, there were few values above the mean available.

Another consideration in this connection is that the results of the observations at the Princeton Station in several of the relations examined failed to be concordant with the results at the other stations.

The marked similarity between the changes in X audibility and relative humidity is even more strikingly shown by an examination of the original curves setting forth the daily observations at the various stations. The diurnal variation in relative humidity corresponds quite closely in many cases to the diurnal variation in X intensity. It is evident that, either X intensity varies directly as the relative humidity, or that both of these variables depend upon a third common factor.

OBSERVATIONS DURING TOTAL SOLAR ECLIPSE.

An expedition was sent to Boulder, Colorado, for the purpose of making observations in signal and X audibility during the period of the total solar eclipse on June 8, 1918, with a view to determining, if possible, the effect of the approaching and departing shadow upon the strength of signals and the intensity of extraneous electrical disturbances.

An antenna of the standard type used at the other stations was erected in open meadow land, entirely devoid of trees and sloping upward to the south, and went toward the mountains, the

TABLE XI.

X Audibility Versus Relative Humidity.

Data	Devens Mar. 4 to May 29	Rockport June 16 to Aug. 1	Monroe Mar. 4 to April 25	Ashland May 11 to Aug. 1	Scriven Mar. 4 to May 19	Princeton June 18 to Aug. 1	Snelling Mar. 4 to June 3	Cornell June 20 to Aug. 1	Leavenworth Mar. 4 to April 2	Madison Mar. 4 to April 24	Brown Mar. 4 to April 24	Oberlin July 3 to Aug. 1	Totals
Similar departures from mean values.....	364	8	271	427	84	52	364	178	81	113	206	94	2244
Opposite departures from mean values.....	190	24	170	277	49	59	219	102	53	55	171	43	1112
Relative humidity was at mean value when X audibility was low.....	109	12	115	117	107	23	227	73	26	86	78	65	1038
Relative humidity was at mean value when X audibility was high.....	29	0	53	53	5	10	104	16	15	3	28	11	327

apex of the V antenna being toward the station at Lyons (YN). While the altitude of the locality was high, sharp granite mountains rose sheer from the plain to a height of three to four thousand feet to the south and west, and at a distance of not more than three-fourths of a mile. To the north and east is rather level prairie. The whole region is rather arid, cultivation being carried on by irrigation. The soil is talus from the mountains, and seems very porous and rocky in the immediate vicinity of the station.

The naval station at San Diego, Cal. (NPL), arranged to transmit special test signals on a 13,300-metre wave according to the following schedule:

Denver Summer Time.

4:10 to 4.15 P.M.	5:20 to 5:25 P.M.
4:20 to 4:30 P.M.	5:35 to 5:40 P.M.
4:40 to 4:45 P.M.	5:50 to 5:55 P.M.
4:55 to 5:00 P.M.	6:05 to 6:10 P.M.
5:10 to 5:15 P.M.	6:20 to 6:30 P.M.

The middle of totality occurred at 5 hours, 22 minutes, 28 seconds.

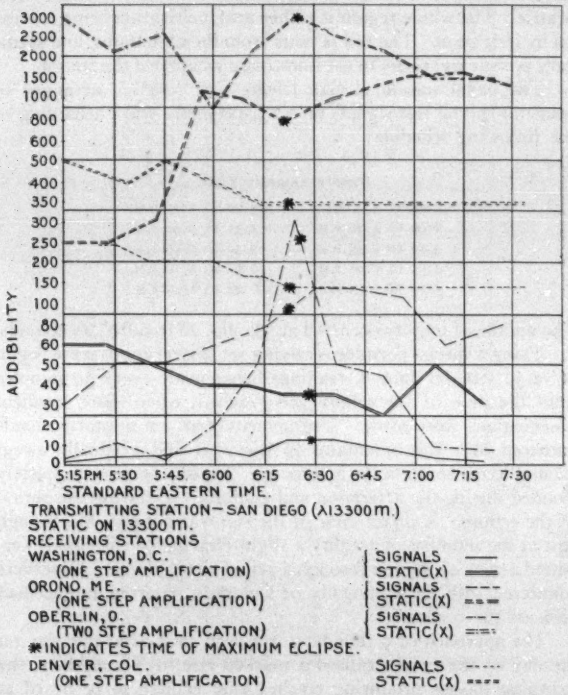
Using a special portable receiving set, observations were begun at 12.30 P.M. on June 8, readings being made every 30 minutes until the time of the eclipse was reached, when more frequent observations were made. Unfortunately at 2 P.M. storm clouds gathered over the mountains to the west and gradually swept around to the south in the afternoon. The sky became completely clouded during the afternoon and continued so during the period of the eclipse. A direct view of the sun was not possible, though just at the moment of totality a slight clearing of the clouds permitted a view of the sun through a veil of cirrus clouds. Observers connected with the University of Colorado reported an excellent view of the corona.

The approach of a thunderstorm very soon after mid-day on the day of the eclipse caused a marked rise in X audibility, the lightning flashes producing crashes loud enough to be heard at considerable distances from the telephone receivers. As a result it was impossible to hear any Transatlantic signals, if indeed they would have been audible otherwise. Signals from NPL and Tuckerton (NWW) could be heard and identified.

Though an increase in signal strength might have been expected during the period of totality, no such increase was observed,

and circumstances were such that all readings made on the signals from the station at San Diego could be checked. In fact, the audibilities taken show an actual decrease, though the decrease

EXHIBIT E.



Effect of partial eclipse of the sun, June 8, 1918, on strength of static and signal audibilities.

is so small as to be accountable on the basis of an error of observation. The gradual and persistent decrease in signal strength, however, up to the time of totality, would appear to indicate some cause other than accident. Late in the evening of the same day the signal audibility was higher than that observed during the

afternoon preceding the eclipse. X audibility readings show a change during the afternoon, but the movement of the storm would naturally account for the changes noted, and as a result would mask any change in X audibility due to the passing shadow.

During the time of the eclipse audibility readings were also made on the signals from the San Diego station at the special receiving station, located at Orono, Ashland, Oberlin and Washington, these stations being in the partial shadow. The data secured at the receiving stations just mentioned appear to show a rise in the audibility during the maximum shadow.

The data secured at Boulder, Col., and at the other receiving stations are shown in the curves as Exhibit E.

Considering the observations made during the eclipse as a whole it may be stated that the results are indecisive with respect to the effect of the shadow upon signal strength and extraneous electrical disturbances, though it may be noted that signal strength at stations in the partial shadow shows an increase at or about the time of maximum shadow.

POTENTIAL GRADIENT OF THE AIR.

A preliminary investigation was conducted in order to determine whether any possible relation existed between the potential gradient of the air and local extraneous disturbances.

The Department of Research in Terrestrial Magnetism, Carnegie Institution, Washington, furnished a series of photographic curves showing the continuous potential gradient as recorded in their Laboratory at Washington, D. C., for the first nine months of 1918.

The nearest special receiving station to Washington was the one located at Ashland, Va., distant approximately 100 miles. It was realized that the potential gradient would probably be different in Washington than at Ashland. But it was considered advisable to make this preliminary study of the potential gradient as a factor. X audibility was the basis of comparison, 50 per cent. above the mean weakly X audibility value was considered high X and 50 per cent. below the mean value, low X.

The mean monthly value of the potential gradient was determined in arbitrary units. In computing this mean value the potential gradient for the month of July was not considered, owing to certain irregularities in the operation of the apparatus

during that period. The potential gradient, even though decidedly variable, was considered positive or negative, as the case might be, if it did not pass to the opposite potential during the period of at least an hour. Mean X audibility values were determined for the station under investigation. See Tables XII and XIII.

TABLE XII.

Tables Showing Comparison Between Potential Gradient of the Air and X Audibility.

Cases in which Potential Was Positive.

	May	June	July	August	September	Total
Similar departures from mean..	26	94	57	39	33	192
Opposite departures from mean.	59	109	53	49	56	273
When potential gradient was at mean value X audibility was low.....	28	73	36	64	20	185
When potential gradient was at mean value X audibility was high.....	18	37	13	32	27	114

Cases in which Potential Was Negative.

	May	June	July	August	September	Total
Similar departures from mean..	2	5	0	3	1	11
Opposite departures from mean.	2	4	3	1	4	11
When potential gradient was at mean value X audibility was low.....	0	0	0	0	1	11
When potential gradient was at mean value X audibility was high.....	0	0	0	0	1	1

TABLE XIII.

Cases in which Potential Gradient Fluctuated from Positive to Negative Values.

	May	June	July	August	September	Total
When X audibility was high ...	6	15	22	5	0	26
When X audibility was low	7	7	0	0	0	14

It will be noted that the greatest number of counts appear in the case of opposite departures, that is to say, when the potential gradient is high the X audibility appears to be low. This result is unexpected.

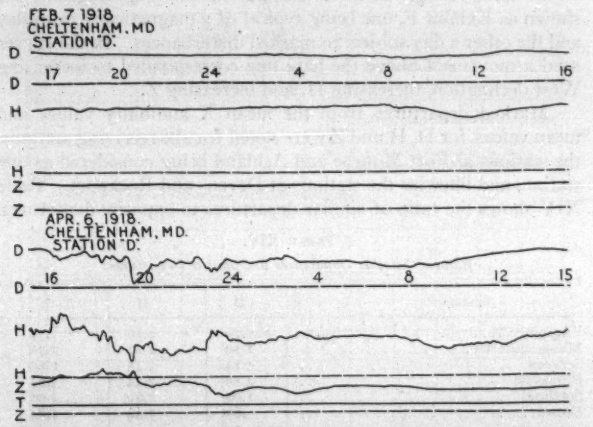
An examination of those cases in which the potential gradient was negative does not show any apparent agreement between X intensity and potential gradient.

In certain cases the potential gradient showed marked rapid

fluctuations from positive to negative values. In a decided majority of such cases the X intensity was found to be high.

As a result of the preliminary investigation above outlined it was decided to secure and install suitable apparatus for photographically recording the potential gradient of the air in the immediate vicinity of a horizontal antenna, the potential of the earth beneath the antenna and the electrical disturbances in the antenna, simultaneously. This investigation was to have been carried out at the Signal Corps Field Laboratory near the City

EXHIBIT F.



of Washington, and the equipment was practically ready for operation at the time the general Transatlantic investigation was discontinued. It is believed that an investigation, such as was projected, would yield valuable data bearing upon the cause of that part of extraneous disturbances which is of local origin.

VARIATIONS IN THE EARTH'S MAGNETIC ELEMENTS VERSUS X INTENSITY.

Passing from a consideration of meteorological elements and their possible relation to extraneous disturbances, it is desired to record the study made of certain other factors in connection with X intensity.

Owing to the fact that, in handling radio telegraph traffic, certain days occur when all receiving stations suffer more or less from what appears to be a general electrical disturbance in nature, thus indicating some general and possibly remote cause, it was decided to compare the variations in X intensity with the variations in the earth's magnetic elements.

Copies of magnetograms from the Magnetic Observatory at Cheltenham, Md., were furnished by the United States Coast and Geodetic Survey. These curves show the declination (D), the horizontal component (H), and the vertical component (Z), of the earth's magnetic field. Several sample magnetograms are shown as Exhibit F, one being typical of a magnetically calm day and the other a day subject to marked disturbances. In the curves used a movement above the base line corresponded to increasing West declination, increasing H, and increasing Z.

Marked departures from the mean X audibility values and mean values for D, H and Z were noted for six receiving stations, the stations at Fort Monroe and Ashland being considered as one station, and likewise the stations at Devens and Rockport. Table XIV shows the ratio of similar departures to opposite departures.

TABLE XIV.

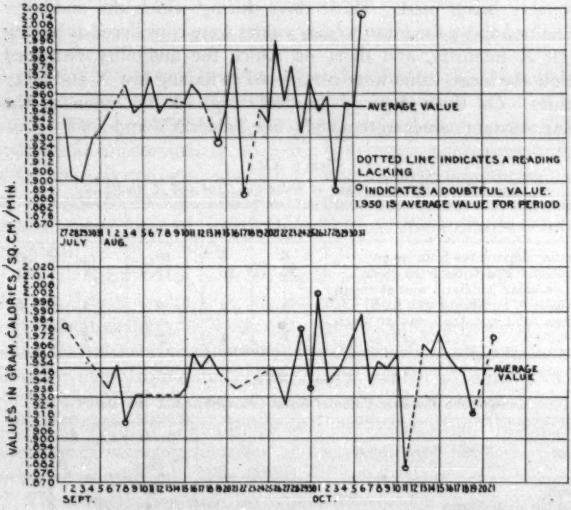
Ratio of Similar Departures to Opposite Departures.

Station	D	H	Z
Virginia	1.76	2.36	1.77
Massachusetts	1.19	2.24	2.79
Screven	1.14	3.45	1.50
Princeton	4.86	2.44	3.83
Snelling	1.04	2.90	2.06
Brown	.87	1.44	1.84
Mean	1.81	2.47	2.29

It will be observed that, in the case of all stations, there were more similar than opposite departures. This is particularly true with respect to H and Z, in the case of H there being nearly two and a half times as many similar as opposite departures. Further, the H curve generally showed a drop near mid-day, the lower values occurring at or after noon in January and about 10 A.M. in June. At about the same time of day D showed a slight fall and a subsequent rise: Z also falls in value. These lower values of the magnetic elements which generally occur at or near mid-

day coincide approximately with the diurnal minimum of X intensity, the latter being referred to in subsequent paragraphs. It would thus appear that a direct relation exists between the variations in the earth's magnetic elements and X intensity, and that extraneous electrical disturbances may be said to vary directly with the intensity of the horizontal and vertical components of the earth's field.

EXHIBIT G.



Solar constant values. Calama, Chile, July 27–October 22, 1918.

VARIATIONS IN THE SOLAR CONSTANT AND X INTENSITY.

Having found what appears to be a definite relation between X intensity and the variations in the earth's magnetic elements, the next natural step was to examine the variations in the solar constant.

The Astrophysical Observatory of the Smithsonian Institution furnished a table of values of the solar radiation constant, the data for which were obtained at Calama, Chile, covering a period

from July 27 to October 23, 1918. A curve showing the variations in the solar constant for the above period was plotted from this data and is shown as Exhibit G. The mean value for the period was found to be 1.950 gram calories per square centimetre per minute. Two comparisons were made. In the first the grade of copy received at the receiving stations was used as a basis. On such days as decidedly poor or good copy was received the solar values were examined. In the second comparison X audibility values were taken as the basis, a mean weekly value of the X intensity being used. Those days during which the audibility remained above the mean weekly values were considered as having high X intensity, and those on which the audibility remained below the mean value were considered as having low X audibility values. On those days of decidedly high or low intensity the solar constant values were noted. See Tables XV and XVI.

TABLE XV.

Comparison Between Value of Solar Constant and X Audibility.

	Ashland	Ithaca	Princeton	Oberlin	Total
Similar departures from mean.....	8	8	16	14	46
Opposite departures from mean....	60	16	17	21	114
When solar constant was at mean value X audibility was high.....	3	2	0	1	6
When solar constant was at mean value.....	1	4	6	2	13

TABLE XVI.

Comparison Between Value of Solar Constant and X Audibility.

Solar Constant Values	Grade of Copy Received	
	Poor	Good
Mean.....	8	3
Slightly above mean.....	5	5
Very high.....	3	1
Slightly below mean.....	2	5
Very low.....	3	1

An examination of these tables discloses the fact that there also appears to be a relation between the value of the solar constant and X intensity, this being apparently more marked at certain stations than at others. It is also interesting to note in this connection that the X intensity appears to vary inversely as the value of the solar constant. Bauer has shown that there is a definite

relation between the solar constant and the earth's magnetism. "In general, the effect of increased solar activity is to cause a decrease in the earth's intensity of magnetism, though there may also be at times a reverse effect." It will thus be seen that the radio data, while perhaps not conclusive, falls into line with what is known with respect to solar and magnetic relations. It is therefore quite probable that the general extraneous electrical disturbances, which are encountered in handling radio telegraphic traffic, are intimately associated, in the last analysis, with solar activity.

GENERAL OBSERVATIONS ON EXTRANEOUS DISTURBANCES.

An examination of the data collected at the several Transatlantic Receiving Stations shows that there is a diurnal variation in the X intensity which has a fairly well defined minimum for all stations at approximately 10 A.M., with a secondary minimum sometimes occurring at about 6.30 P.M. The maximum values occur between 10 P.M. and 4 A.M., the highest value commonly occurring about 3 A.M., with a secondary maximum shortly before midnight.

While there exists, as noted above, a more or less well-defined diurnal change common to all stations, it is true that frequent and radical changes in X intensity may occur at a given station which do not manifest themselves simultaneously at other stations. This is evident from a study of the data presented in Tables XVII, XVIII and XIX. In preparing these tables only abrupt departures of X intensity from mean values were considered. Instances when the X intensity remained at 8000 audibility for some time were not considered. The tables are self-explanatory.

The investigation was also extended to include an examination of those cases in which radical similar departures from the mean X audibility occurred at one station within a period of two hours prior to, or subsequently to, a similar occurrence at the other station. The results are embodied in Table XX.

The foregoing data lead to several important observations. From the first two tables of this group it is evident that in no case does the X audibility exhibit a simultaneous similar marked change at all six stations, or even at five of the stations, and shows only two similar departures at five stations within a period of two

TABLE XVII.

Agreement of Radical Changes in X Audibility at Same Hour.

Date	Number of days	Number of stations where changes in X intensity agree			
		2 stations	3 stations	4 stations	5 stations
February 1–March 15	42	46	16	3	0
March 15–May 23	68	43	17	5	0
May 23–August 1	70	58	9	0	0
Total	..	147	42	8	0

TABLE XVIII.

Agreement of Radical Changes in X Audibility Within Two Hours.

Date	Number of days	Number of stations where changes in X intensity agree			
		2 stations	3 stations	4 stations	5 stations
February 1–March 15	42	35	22	1	2
March 15–May 23	68	45	13	1	0
May 23–August 1	70	38	14	2	0
Total	..	118	49	4	2

TABLE XIX.

Opposite Radical Departures of X Audibility from Averages at Special Radio Station at Same Hour.

Date	Number of days	Number of stations where changes in X intensity is opposite			
		2 stations	3 stations 2 agree 1 opposite	4 stations 2 high 2 low	4 stations
February 1–March 15	42	15	10	0	1
March 15–May 23	68	18	4	2	1
May 23–August 1	70	19	6	0	0
Total	..	52	20	2	2

TABLE XX.

	February	March	April	May	June	July	Total
X audibility change earlier in Massachusetts than in Virginia	5	1	2	8	1	1	18
X audibility change earlier in Virginia than in Massachusetts	4	2	9	5	0	2	22

hours. This would appear to indicate that at least a portion of the extraneous electrical disturbances which give rise to interference and radio communications, are of comparatively local origin. It will be noted that there were 147 cases where the disturbed conditions at the two stations exhibited simultaneous radical changes, and 118 cases where the changes occurred within two hours. From this, it might be inferred that the disturbance which gives rise to X's moves. Since there were 52 cases of opposite simultaneous departures, it would also appear to be evident that at least a portion of the disturbance is not entirely local in origin. It may be of interest to note that it was found that radical changes occurred more frequently in the period preceding March 15 than later, and that the change in X audibility is somewhat more apt to occur earlier in Virginia than in Massachusetts, since in the copy made, the changes occurred 22 times in Virginia before they did in Massachusetts, as against 18 times in Massachusetts before the occurrence in Virginia.

In dealing with the results of extraneous interference, it is both interesting and significant to note that during the period covered by the operation of the Special Transatlantic Stations, it frequently occurred that an inland station would be able to secure portions of copy lost by all of the coastal stations. For example, the station at Ithaca and, at times, the one located in Ohio, would secure words or phrases which the coastal stations were unable to copy. Similar instances occurred with respect to Transpacific operation. At least on two occasions the Signal Corps Special Receiving Station, located at Fort Leavenworth, was able to read the Naval station at Pearl Harbor attempting to work the station at San Diego when the latter station, as indicated by service messages, was experiencing great difficulty in copying the former station.

While dealing with the question of general electrical disturbance, it is found interesting to note the frequency of electrical storms in different regions as shown by charts published in the *Monthly Weather Review* for July, 1915, as part of a paper by Mr. W. H. Alexander. At some period during the Transatlantic investigation, five receiving stations were located on or near the same 400-storm line, two near the same 300-line, two near the same 200-line (the Sault St. Marie station which was installed just as the observations were discontinued would also have been

on the same 200-line) and one on the 100-line. As a result of the experience gained during the observations, it would appear to be true that so far as that part of the extraneous electrical disturbance which is of local origin, particularly that due to electrical storms, is concerned, the ten-year storm map may serve as a rough guide with reference to the possibility of X intensity in a given region. It had been planned to make a radio survey of the region covered by the states of Oregon and Washington, where, as shown on the storm map, only 25 thunder storms occurred during a period of ten years, and what is possibly more significant, no storm lines of high value pass near that region. The projected survey was not carried out owing to the discontinuance of the investigation as a whole.

In selecting sites in new regions to be investigated, a very interesting and important factor was encountered. In certain localities it was found that a change of less than a mile in the site of the station resulted, in a number of cases, in a decided modification in both the X intensity and strength of signals. The observation just referred to, and other considerations, led to the practice of carrying out preliminary radio surveys of a given region before a final site was determined on for a test station. For example, before deciding upon the location of the station at Van Buren, Maine, two preliminary surveys were made on the eastern half of the state. One survey included Houlton, Caribou, Van Buren, and Ft. Kent. During a late survey, simultaneous observations were made at Bar Harbor, Orono, Houlton, and Van Buren.

In carrying out this and other similar surveys, use was made of special portable receiving sets in conjunction with a single wire low horizontal antenna, the receiving sets having previously been compared at some given station. The results secured at the preliminary sites were then carefully compared with respect to X intensity and signal strength, the ratio of these two factors and also the actual copy secured serving as a basis of comparison. While referring to the matter of surveys, it may be stated that radio surveys similar to the above were carried out in the region of the Oberlin, Ann Arbor, and Madison stations. Such a survey was also made of the region about Sault St. Marie before establishing at that point. It is believed that such surveys are invaluable in a preliminary determination of optimum receiving centres.

SIGNAL STRENGTH.

Turning now to the question of the other variable in radio work, namely, changes in signal strength (audibility), it may be said that this phase of the general problem was given careful attention. In studying the variations in signal strength the traffic from the station at Lyons, France (YN), was taken as a basis.

An examination of the records showing the mean daily signal audibility of Lyons (LN) as noted at three of the receiving stations, indicates that the signals from a given station may show a comparatively high audibility value at one or more of the stations on a certain date and at the same time a low value at another station, and *vice versa*. It is also evident that the signals from a given transmitting station may have a high audibility value at a given receiving station on a certain date, while signals from some other station are comparatively weak at that particular time, and *vice versa*. It was also found that a given station might show a comparatively satisfactory signal audibility for a period of time of the order of a month or several months, while during some other period the signal audibility would be found to be low.

An effort was made to determine whether barometric conditions over the North Atlantic Ocean bore any possible relation to the variations in signals from the station at Lyons. Charts covering the month of March, 1918, were prepared for use in this investigation by the Weather Bureau and showed barometric areas across the North Atlantic, especially in the region of the great circle passing through New York and Rome, and near Lyons. The data available for the compilation of the charts above referred to were limited, owing to military conditions. The data showed that when a low barometric area in Midatlantic existed on the great circle referred to the signals at Devens had decidedly low values in seven cases and decidedly high values in two cases. At the Fort Monroe Station, under the above conditions, the signal audibility showed a decidedly low value in ten cases and high values in seven cases. The following table (XXI) shows a comparison between the audibility of the Lyons signals and the condition of the sky over the Atlantic on the great circle above indicated.

In the above connection it should be noted that during the period considered lows obtained across or above the particular great circle and highs below. At no time during the month was

there a high off the North American coast or in the middle of the ocean over the circle. The only locality where high areas occurred was on the European coast. From an examination of the limited data available it would appear that a low pressure area on the great circle in Midatlantic tends to result in low signal audibility on the American Continent. There is also some evidence for the tentative conclusion that cloudiness over the Atlantic on the great circle results in low signal values at the receiving stations. Owing, however, to the limited amount of data available for this particular phase of the investigation, it would obviously be profitable to extend the study over a longer period under conditions favorable to the securing of more complete data.

TABLE XXI.

At Devens, Massachusetts	Low signal audibility	High signal audibility
(Sky condition)		
Blue sky	2 times	2 times
Partly cloudy	6 times	2 times
Cloudy	4 times	4 times
At Port Monroe, Virginia	**Low signal audibility**	**High signal audibility**
(Sky condition)		
Blue sky	1 time	3 times
Partly cloudy	5 times	4 times
Cloudy	7 times	4 times

Charts were prepared setting forth the hours at which the signals from a given station (Lyons) have maximum and minimum values, respectively. These charts clearly indicated that the maximum and minimum values do not necessarily occur simultaneously at the several receiving stations. These charts also show that the maximum and minimum values at a given receiving station on a given day may obtain for a period of several hours; further, these maximum and minimum values do not occur at the same hour each day and appear to bear no definite relation to the time of sunrise, except possibly that the maxima are more apt to occur in the forenoon, prior to 10 A.M. This latter observation is evident from the data recorded subsequently to approximately August 1, at which time Lyons began to work a daily schedule which extended practically throughout 24 hours.

It is also desired to direct attention to a period of unusually

high signal audibility during the latter part of March. The audibility values just referred to were more or less common to all the receiving stations, and applied to the signals from the stations at Rome, Carnarvon and Lyons. This phenomenon was also noted by the Navy Department. The writer is informed that the records of the Department of Research in Terrestrial Magnetism of the Carnegie Institution show that an abnormally high value of the electrical conductivity of the air occurred on March 21. This date falls within the period of abnormally high audibility values above referred to. This, of course, may be only a coincidence, and yet the occurrence naturally suggests the advisability of investigating the possible relation of the conductivity of the atmosphere to radio signal strength. In order to accomplish this satisfactorily it would be necessary to establish a chain of observatories between the transmitting and receiving stations in order to secure reasonably comprehensive data with reference to the conductivity of the air.

The experience gained during the Transatlantic investigation shows that a given receiving station does not necessarily functionate equally well in receiving from all transmitting stations. For example, the station at Fort Screven, Ga., was never able to secure satisfactory signals from Rome; the station at Oberlin, Ohio, was more or less unsuccessful in receiving the station at Nauen, Germany; and the station at Madison could not successfully secure copy from the station at Lyons.

Experience also leads to the conclusion that comparatively little energy from the European stations, particularly from the station at Lyons, passes beyond the Great Lakes. The station was installed at Sault St. Marie, Mich., to further investigate this point, but the termination of the Transatlantic investigation prevented the carrying out of this part of the program. However, the results of a preliminary radio survey made in the region of Sault St. Marie tend to show the latter site would prove to be a fairly satisfactory inland receiving centre.

Since the signal strength of all European stations as received at the Signal Corps station at Ithaca, N. Y., was always comparatively high, and since the storm map before referred to shows fewer electrical storms in the northern part of New York State in the region of the St. Lawrence River than at Ithaca, it was planned to investigate the region of the St. Lawrence River.

The closing of the experimental work also prevented the carrying out of this survey. In view of the facts just stated, and also because of the fact that the great circle from Lyons passes approximately down the St. Lawrence River Valley, it is believed that a radio survey of that region in New York should be made.

In general it may be said that the stations at Rockport, Mass., and Princeton, N. J., experienced the strongest signals, with the Ithaca station ranking next. The Virginia and Maine stations showed signal values of the same order of magnitude, but of decidedly lower value than the stations above mentioned. The signal strength at Oberlin was of the same order as that which obtained at the Maine and Virginia stations. As previously stated various steps were taken to check the above indicated result. Certain additional checks were about to be made just as the work was terminated. If the data extending over nearly a year are at all indicative of actual conditions, it would appear that the geographical distance of the receiving station from the transmitting station is not by any means the only important factor in predetermining received signal strength.

INVESTIGATION OF ANTI-X DEVICES AND AGENCIES.

At the same time that data bearing on X's and signal strength were being collected and studied, an effort was also made to investigate various suggested and original anti-X devices and agencies. In order to carry out this feature of the work most effectively a field laboratory was installed in Maryland just outside of the District, west of Washington. The equipment was sheltered in a portable house similar to those used at several of the receiving stations. The site of the laboratory was in an open field, the temporary use of which was donated by patriotic citizens of Washington, thus affording excellent opportunity for thoroughly testing various antenna systems and other anti-X devices.

Starting with the well-known fact that a low horizontal antenna is less subject to extraneous electrical disturbances than one of the vertical type, a number of antenna arrangements and other devices were investigated with respect to their anti-X properties. While X's and signal audibility measurements were made in each case, the final tests as to the effectiveness of any given device or agency was whether an operator could actually make better copy with the apparatus under test than with the standard low horizontal antenna.

Previously to the experiments at the Field Laboratory above referred to, helices, 15 ft. square (see Fig. 3), were constructed at Camp Devens, Ft. Brown, Ft. Screven, and Ft. Monroe stations, and a 12 ft. helix at the Oberlin station. The winding of the 15-foot helices consisted of 40 turns of stranded copper wire, spaced ¼ inch between centres. The 12-foot helix had 45 turns. The helices at Camp Devens, Ft. Brown, and Oberlin were housed. Tests were carried out to determine the relative effectiveness of these helices when compared with the horizontal antennas used at the stations. The evidence showed conclusively that the helices did not possess any advantage over the horizontal antennas. The ratio was not improved and at times the signals on the helices were prohibitively weak.

Both audio and radio balancing between two helices at right angles were tried in an effort to neutralize the X effects, but without success. Simultaneous photographic records of X impulses received on two helices placed at right angles to one another and in a vertical plane appear to show that the extraneous disturbances do not occur simultaneously at two mutually perpendicular planes. The amplitude of the impulses recorded is not significant. In making these records the receiving and recording apparatus were interchanged from time to time in order, as far as possible, to eliminate experimental errors. In making these records the helices had a common vertical axis and it is possible that electrostatic coupling between the two helices existed. In view of this possibility, these tests should be repeated with the helices placed far enough apart to reduce the coupling to a negligible quantity.

The screening of a horizontal antenna was also investigated. A horizontal thousand-foot (305 metres) single-wire antenna was placed at a mean distance of approximately 3 feet (0.9 metres) above the ground and enclosed in a screening system composed of closed loops of copper wire 18 inches (45.8 cm.) in diameter, the plane of the loops being vertical and spaced at a distance of 20 inches (50.8 cm.). These loops were connected by high resistance wire and the screening system was grounded at several points throughout its length through 2500 ohm resistance units. Repeated tests showed that such a screening system possessed no advantages over an unscreened system.

It has been suggested that a mechanical covering for the antenna system might prevent the deposition of local electrical

charges on the wire of the antenna, with the attendant electrical disturbance. In this connection, it may be noted that the large helices, referred to above, were constructed of insulated wire, and several of the helices were used within a building. No noticeable difference was observed, so far as X's are concerned, between the behavior of the helices operated in the open or enclosed. Further tests along this line were carried out at the Field Laboratory. Careful measurements were made on two horizontal antennas, the wire of one of which was covered with a light insulating material having a comparatively low specific inductive capacity, and an antenna constructed of bare wire, but otherwise identical. No difference in the functioning of these two antennas could be detected.

It was thought that possibly an antenna having concentrated capacity might be less subject to extraneous electrical impulses than one composed of long wire. An antenna consisting of 600 square feet (55.74 square metres) of copper window screen, and supported at various heights above the earth's surface up to 12 feet (3.7 metres), was compared with a 1000-feet (305 metres) horizontal antenna consisting of 2 wires. The signal strength on the copper screen antenna was prohibitively low, and the ratio showed no improvement over the usual horizontal antenna.

Another anti-X possibility investigated consisted of a vertical subterranean antenna. At Dumfries, Va., about thirty miles (48.3 Km.) south of the City of Washington, is located the Cabin Branch Mine, which produces iron and copper pyrites. There is in this mine a vertical shaft 1000 feet (305 metres) deep. A series of preliminary comparative tests was made at this mine in April, and a more complete series of experiments was carried out in the latter part of July. A vertical insulated wire, approximately 1000 feet long, was suspended in this shaft, and a receiving set connected to the upper end, various earth connections being tried, such as steam and water pipes in contact with moist earth.

For a basis of comparison, an antenna consisting of a single horizontal wire, 1000 feet long, was extended over the ground to the southwest from the mine entrance, and supported on trees high enough above the earth to clear the surface vegetation; the maximum height of this wire did not exceed 4 feet (1.2 metres).

A careful comparison was made between the X intensity and signal strength when using the horizontal and the pendant an-

tennas. Signals from the station at Lyons (YN), France, and Carnarvon (CV or PI), Wales, were easily readable on the pendant antenna. The signal strength when using the pendant antenna was always less than when using the horizontal wire inside the mine. Extraneous disturbances were noted when using the pendant antenna. The ratio, however, between X's and signals was in all cases found to be greater (less favorable) when using the pendant antenna than when employing the horizontal wire.

The receiving set was also connected to the lower end of the pendant wire, earth connection being made to piping at the bottom of the mine. Under the above conditions signals from Lyons (YN), France, were heard loud enough to be identified, but were not loud enough to make copy possible, and the ratio was unfavorable. Signals from several high power American stations were heard with comparatively high audibilities when the receiving apparatus was connected to either the upper or lower end of the pendant wire.

Following is a table giving the data secured during the tests made in July:

TABLE XXII.

Day	Hour	Antenna	Station	Audibility		Signal Static
				Static	Station	Ratio
7/28	8 : 55 A. M.	Outside	Y. N.	140	40	3.5
7/28	8 : 55 A. M.	Top mine	(Y. N.) stopped	170	..	....
7/28	9 : 20 A. M.	Outside	P. I.	200	80	2.5
7/28	9 : 20 A. M.	Top mine	P. I.	170	40	4.25
7/28	9 : 25 A. M.	Top mine	Y. N.	200	18	11.1
7/28	9 : 25 A. M.	Outside	Y. N.	170	50	3.4
7/28	12 : 00 M.	Bottom mine	(15000 M.)	40 (No stations)		
7/28	3 : 00 P. M.	Outside	P. O. Z.	8000+	250	32
7/28	3 : 00 P. M.	Mine	P. O. Z. not heard	8000+	...	....
7/28	10 : 00 P. M.	Outside	.....	250	....	....
7/28	10 : 00 P. M.	Mine	.....	300	....	....
7/29	8 : 00 A. M.	Outside	Y. N.	100	35	2.8
7/29	8 : 00 A. M.	Top mine	Y. N.	60	12	5
7/29	8 : 45 A. M.	Bottom mine	15000 M.	26 (No station)		
7/29	8 : 45 A. M.	Bottom mine	W. G. G.	26	8000−	307
7/29	8 : 45 A. M.	Bottom mine	W. I. I.	(Standing by)		
7/29	9 : 00 A. M.	Bottom mine	Y. N.	26	5	5.2
7/29	10 : 55 A. M.	Bottom mine	Y. N.	50	6	8.3

The tests with subterranean vertical antenna show that a receiving system of this type does not possess any advantages with respect to the elimination of extraneous disturbances over low horizontal type of antenna. A pendant antenna, however, might possess certain more or less obvious military values. It is believed these subterranean tests should be extended to include experiments in coal and other mines, setting both vertical antenna and also horizontal wires at different levels beneath the surface of the earth.

RADIO TRANSLATOR.

The most promising device for the elimination of extraneous disturbances, including interference from other stations which we have investigated, is a device designed by this Branch, a working model having been constructed in the Signal Corps Field Laboratory. Briefly, this device consists of a tuned reed associated with an electromagnetic system, and an external acoustic resonating chamber. Drawings showing several different ways of assembling the parts are shown as Exhibit N.

The telephone receiver commonly employed in connection with radio reception is incorrectly designed for use in radio work. The telephone receiver was originally constructed to reproduce the voice with its many overtones, hence the diaphragm is highly damped and has a comparatively flat resonance curve. The result of such a construction is that X and other extraneous impulses excite the diaphragm, as well as the signals themselves. The signal impulses from a radio receiving set closely approximate a monotone; that is, the signal tone is comparatively free from overtones or upper partials. Quality or timbre therefore need not be considered in arranging to translate these electrical impulses into audible sounds. It therefore becomes possible to design a translating device for use in radio work which will be highly selective with respect to signal tones and which will respond but feebly to impulses out of resonance with the vibrating member.

Proceeding along the lines just indicated, the device referred to in the second paragraph above has been developed. By the use of a comparatively stiff steel reed, R, of the proper coefficient of elasticity, and fastened at one end only, the so-called "musical effect" of the X's, commonly present in other similar devices, is very much reduced. The proper mechanical relation of the resonant chamber, C, to the reed is important. Energy from the

resonant chamber is conveyed to the ears of the operator by means of short rubber tubes similar to those of a stethoscope. The device

EXHIBIT N.

FIG. 1.

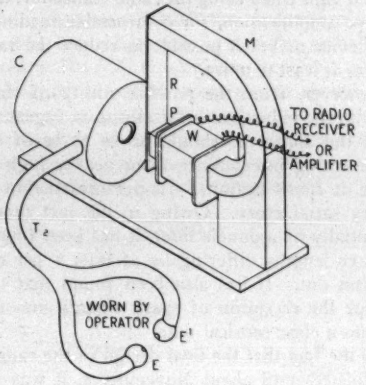


FIG. 2.

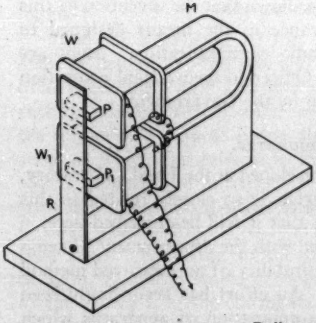
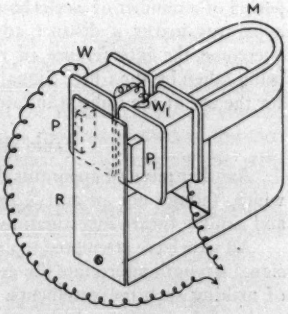


FIG. 3.



Radio translator.

is exceedingly simple and robust. It is preferable to enclose the resonant chamber and the electromagnetic parts in such a manner as to prevent extraneous noises and air-currents from acting upon

the resonant chamber. The efficiency of this device, which might be called a radio translator, is not as high as the best receivers used for radio purposes, but repeated tests show that the ratio of the X's to signals is materially improved by the use of this apparatus, and high when using the radio translator, in connection with two steps amplification, for comfortable reading. The use of the new device makes it possible to reduce the ratio in practically all cases at least to unity.

Aside, however, from the possible utility of this device in connection with the reduction of the effects of vagrant extraneous disturbances, the apparatus should prove to be of considerable utility in preventing interference from nearby high power continuous wave or spark stations. Its performance in this respect has been very satisfactory. Owing to the fact that the device consists essentially of a double filter, it has been found by actual tests that wave lengths differing by at least 1 per cent. can be completely shut out. It has also been found that this receiver when used for the reception of spark signals smoothes out the spark tone into a clear musical note.

Owing to the fact that the final design of the radio translator was not completed until about November 1, it was not possible to give the device a trial at the several receiving stations, but practical tests made at the Field Laboratory extending over a period of a number of weeks have shown that the invention of this apparatus marks a distinct advance in the means designed to overcome the interference in radio communication. Steps are being taken by the Chief Signal Officer to secure legal protection for the use of the radio translator by the Government.

RADIO AUDIOMETER.

Another piece of apparatus developed at the Field Laboratory, which, though not an anti-X device, is so closely related to this and similar future investigations that it will be described here.

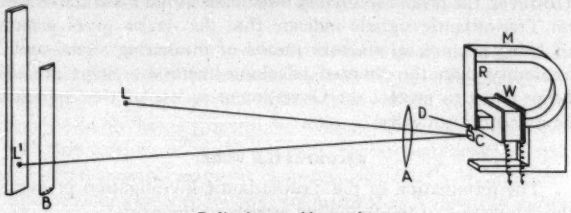
All who have attempted to deal with the measurement of radio signal strength appreciate the desirability of an improved method of making such measurements. An effort has accordingly been made to devise some device or combination of apparatus which might give results that are more nearly quantitative than those obtainable by the shunted telephone method.

Reference has just been made to a piece of apparatus designed by the Transatlantic Branch to be utilized for the purpose of

eliminating extraneous disturbances of various types. Using the electromagnetic system of the radio translator basis, a device was designed which gives promise of being a satisfactory quantitative method of measuring the intensity of radio signals and X intensity.

The drawing listed as Exhibit O shows the construction of the device. The electromagnetic system W actually used was that taken from a P-11 W E telephone receiver. The steel reed R was a portion of an artist's spatula, and should, in practice, be just stiff enough to prevent it being drawn to the pole pieces of the electromagnets when adjusted a distance from the same giving maximum sensitiveness. The length of the reed used depends upon the pitch of the beat tone desired.

EXHIBIT O.



Radio photographic recorder.

If a tiny mirror, C, of the order of a square millimetre in area, be fastened to the free end of the metal reed, R, by means of an exceedingly light and short piece of very flexible material, D, such as celluloid or collodion, and the reed is caused to vibrate, the mirror will tend to rotate about the axis located in the thin strip to which the mirror is fastened.[2] By making the strip which supports the mirror very short a beam of light reflected from the mirror to a scale 70 centimetres away will be moved through a distance equal to 2500 times the amplitude of the metal reed itself. Referring to the drawing, L is a suitable source of light, A and B lenses arranged to give a well-defined image of the source L at the conjugate focal point L, this image being received on a suitable scale or sensitive photographic paper. Sig-

[2] NOTE.—The Officer-in-Charge is indebted to Doctor Edwards, formerly of Bureau of Standards, for the suggestion of this means of optical multiplication.

nals having an audibility of 15 will give a deflection of 2 millimetres on the scale. A deflection of this magnitude is ample for photographic recording purposes and may readily be increased, by amplifying the signals or using a greater scale distance. For quantitative measurements the deflection may be read directly on the scale or by means of a second optical system. The essential parts of the apparatus are exceedingly simple and the device is very sensitive, having a higher sensibility and being decidedly more rugged than the similar apparatus made by the General Electric Company. X impulses affect the system, giving sufficiently marked deflections, for quantitative measurements.

Owing to the fact that the device was not developed until about December 1, samples could not be constructed and used for making quantitative measurements at the special receiving stations. However, the results secured in tests made at the Field Laboratory on Transatlantic signals indicate that the device gives promise of being a more satisfactory means of measuring signal and X audibility than the shunted telephone method. Steps are also being taken to protect the Government in use of this apparatus as a recording device.

UNCOMPLETED WORK.

The termination of the Transatlantic investigation prevented the completion of the following aspects of the work:

(*a*) The securing of data at Sault St. Marie, Mich., which was to have completed the radio survey of the Great Lakes Region.

(*b*) The investigation of the region adjoining the St. Lawrence River Valley in northern New York State, and also the Pacific Coast Region.

(*c*) The final checking of relative signal audibility values at the various stations by means of new and improved apparatus.

(*d*) The carrying out of a study of the simultaneous occurrences of X impulses in three mutually perpendicular planes.

(*e*) The securing of simultaneous photographic records of X impulses at a number of widely separated points, with a view to determining what part of such impulses are of local origin and what part is general in character.

(*f*) The study of the simultaneous potential of air in the immediate vicinity of an antenna, the earth beneath the antenna and the X impulses in the antenna, by means of photographic recording devices.

(*g*) The investigation of the functioning of both vertical and horizontal subterranean antennas.

GENERAL SUMMARY.

The extraneous electrical disturbances (X's) encountered in radio communication are undoubtedly composite in character, a part being more or less of local origin and a part having a remote genesis. The evidence appears to indicate that the local X's probably depend upon the combined effect of several meteorological factors, the velocity of the wind and the temperature of the air being important considerations, X intensity varying inversely as the factors just named.

A marked agreement was found to exist between relative humidity and the intensity of X's. Either the latter is a function of the former or there exists a common controlling factor.

Marked local differences in the X intensity undoubtedly exist, differences in station sites of the order of a mile resulting in decided differences in X intensity, and sometimes in signal strength.

Ten-year storm charts are found to serve as a rough guide as to the local X intensity which will be encountered in given regions.

That part of the electrical disturbances which is of a general nature probably has its origin in solar activity, it having been found that variations in X intensity correspond directly with changes in the earth's magnetic elements, particularly H, and there being also some evidence for the conclusion that X intensity varies inversely as the solar radiation constant.

There exists a diurnal variation in X intensity for all stations which has a fairly well defined minimum occurring at 10 A.M. The maximum values occur between 10 P.M. and 4 A.M., most frequently at 3 A.M.

A given receiving centre will not functionate equally well with respect to reception from different transmitting stations.

Maximum and minimum values of signal strength from a given transmitting station do not always occur simultaneously at different receiving stations.

A receiving station's effectiveness may vary from season to season and even from month to month, this being particularly true of inland stations.

A comparatively small amount of energy from the European stations, particularly Lyons (YN), passes beyond the region of the Great Lakes.

Within certain limits, geographical distances from the transmitting station are of secondary importance in determining the quantity of radiated energy which reaches a given receiving station.

Local as well as general radio survey should be made before definitely deciding upon permanent sites for receiving centres.

Transatlantic radio traffic can be handled at practically any point on the Atlantic Coast from Ft. Monroe northward, the ratio between X's and signals, however, was found to be more satisfactory at certain points at or near the coast than at others.

The immediate vicinity of Washington is probably as satisfactory for a receiving centre as any point near the Atlantic Coast south of Massachusetts.

The northeastern section of Maine is believed to be the most satisfactory point for Transatlantic reception.

Inland stations frequently secure portions of copy missed by all coastal stations.

Because of the fact that violent local electrical disturbances may occur, and because maximum and minimum values of signal strength do not necessarily occur simultaneously at all places, it is desirable to have several receiving centres in operation at the same time. It is believed that uninterrupted service can be maintained by establishing three such receiving centres, one of these centres to be located just outside the City of Washington, one in northeastern Maine, and one in northern New York State in the vicinity of the St. Lawrence River. The copy secured at the Washington station should serve as a basis, missing parts being supplied from the other receiving centres. The land line tolls would thus be reduced to a minimum.

The Signal Corps Transatlantic receiving stations could have handled the entire incoming traffic on and after August 1, 1918.

A device has been designed which reduces the X-signal ratio, and also eliminates interference from other stations if the wave length differs by one per cent. This device also changes the tone of a spark station to a pure musical note.

A simple quantitative method of high sensitiveness for measuring X intensity and signal strength has been developed. This apparatus may be utilized for the purpose of securing photographic records of radiograms.

In conclusion it is desired to record that a number of private individuals, educational institutions, and other organizations rendered valuable assistance during the course of the Transatlantic investigation by the loan of the use of land, buildings, and special apparatus.

WASHINGTON, D. C.,
December 31, 1918.

Aerial Photographic Mapping. M. A. KINNEY, JR. (*Flying*, vol. viii, No. 3, p. 250, April, 1919.)—No development brought about in the heat of intense war effort has greater peace time significance than that of aerial photography; aerial photography has opened an entirely new field of endeavor. Whereas the ordinary map surveyor would have to make his calculations on a yearly basis, the aerial photographic surveyor estimates from the standpoint of hours. By aerial photography, a map just as accurate as that produced by the surveyor, and far more comprehensive, can be made available within forty-eight hours after the flight to take the exposures.

When the armistice was signed, a number of automatic and semi-automatic cameras had been produced, ranging in size from the 4 x 5 camera with 8.5 inches focal length to the enormous cameras of 50 inch focal length and 8 x 10 plates. One of the most ingenious of these cameras is the Eastman K-1. This camera is entirely automatic in its action. It is set on the floor of the fuselage and operated by a controlled wind turbine. Roll film is used, and 100 pictures 8 inches by 10 inches in size can be made without reloading. The use of film of such large size presented a very great problem because of vibration. The difficulty was overcome by providing a vacuum suction which accurately holds the film in the recording plane without liability of static. This K-1 camera can in one continuous trip at an altitude of 10,000 feet take sufficient exposures to cover an area of some 200 square miles.

Photographic mapping can be accomplished by flying at a height of 10,000 feet using the K-1 automatic camera which will record approximately two square miles of area at the height named at each exposure. The photographs gathered on a mapping trip can be pieced together in an accurate mosaic by a method of triangulation. The photographic map on completion may be traced and interpreted into the usual form of topographical map. The work of developing and printing, piecing the photograph in mosaics, and tracing can be accomplished in a remarkably short time.

The Geophone. ANON. (*Communication, U. S. Bureau of Mines,* March 27, 1919.)—The geophone, a listening instrument invented by the French during the war to detect enemy sapping and underground mining operations and for the location of enemy artillery, is now being used by the Bureau of Mines as a possible aid in locating miners who have been entombed after a disaster. The instrument was developed by United States engineers during the war and is now used by the bureau according to plans drawn by these engineers. Alan Leighton, assistant chemist of the bureau, who now has charge of these investigations for the bureau, has given the following statement of general information regarding the geophone:

The instrument, though small, is essentially a seismograph, since it operates on the same principle as the ponderous apparatus with which earthquake tremors are recorded. It consists of an iron ring about three and a half inches in diameter within which is suspended a lead disc fastened by a single bolt concentrically to two mica discs, one of which covers the top and the other the bottom of the ring. Two brass cap-pieces cover the discs, the top one having an opening in its centre to which is attached a rubber tube leading to a stethoscopic ear-piece. These cap-pieces are fastened with bolts to the iron ring and serve to hold the mica discs in place. Essentially the apparatus is merely a lead weight suspended between two mica discs cutting across a small air-tight box. If the instrument is placed on the ground and any one is pounding or digging in the vicinity, energy is transmitted as wave-motion to the earth, and the earth-waves shake the geophone case. The lead weight, because of its mass and elastic suspension between the mica discs, remains comparatively motionless. There is thus produced a relative motion between the instrument case and the lead weight. The result is that a compression and rarefaction of the air in the instrument takes place. Since the rubber tube leading to the ear-piece is connected with this space in the geophone, this compression and rarefaction is carried to the ear-drums.

When two instruments are used, it has been found that the sound is apparently louder from the instrument nearer the source of the sound. By moving the instrument properly, a point can be found where the sound will be of the same apparent intensity in both ears. The direction of the sound is then on a perpendicular to the line joining the centres of the two instruments either in front of or behind the observer; further observation will show which side. Direction is quite accurately determined in this way. The sound is not actually louder in one ear than in the other, but the ear is capable of distinguishing the difference in time at which the sound arrives in the two instruments. Since this is the case, persons who are slightly deaf in one ear are said to still be able to determine direction with the instrument.

THE VAPOR TENSIONS OF THE METALS.*

BY

J. W. RICHARDS,

Professor of Metallurgy, Lehigh University.
Secretary of the American Electrochemical Society.
Member of the Institute.

It has been known for centuries that mercury could be boiled under atmospheric pressure, and it has been known for a long time that some other metals are volatile at high temperatures. We can at once state the general conclusion that all metals are volatile, or possess characteristic maximum vapor tensions at any given temperature.

Volatility, or exertion of vapor tension, is generally thought of in connection with liquids, and we speak of their normal boiling points as the temperature at which their vapor can exert 1 atmosphere pressure (760 mm. of mercury column). With many metals this single datum is the only one known; with a few, *e.g.*, mercury, cadmium, zinc, sodium, lead, thallium, bismuth, tin, silver and copper, several or many similar data have been determined, enabling us to plot to a greater or less extent their vapor tension curves.

Solids, however, can exert vapor tension, and the vapor tension of the solid at the melting point is the same as that of the liquid. The two curves, however, are not prolongations of each other; there is a cusp or bend in the curve at the melting point, the vapor tension of the solid being always *less* than the extrapolation of the curve for the liquid below the melting point. This behavior we know to be true of all materials (elements or compounds) whose vapor tensions in the solid and liquid states, below and above their melting points, have been determined, such as sulfur, iodine, bromine, water, and many inorganic and organic compounds.

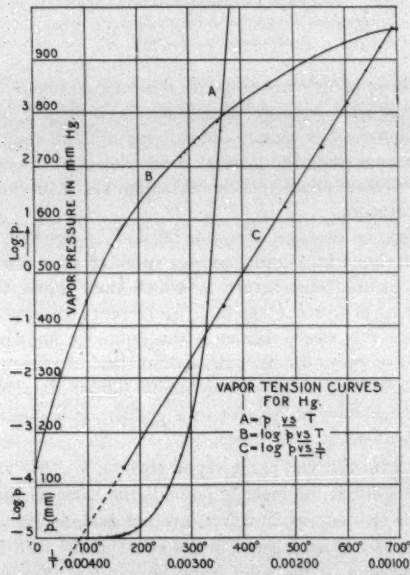
* Presented at a meeting of the Section of Physics and Chemistry held Tuesday, December 10, 1918.

VAPOR TENSION CURVES.

(A) Vapor Tension Plotted Against Temperature.

This is the simplest and most natural chart to make. It means simply charting the observed maximum vapor tensions against determined temperatures. Figure 1, line *A*, shows this for

FIG. 1.



mercury. It will be noted that the curve is very flat at low temperatures and very steep at high temperatures. Such curves are difficult to draw, also difficult to interpolate accurately and almost impossible to extrapolate beyond observation points with any degree of probability. They are serviceable only within the limits covered by the experimental data, and even then are not very manageable. They cannot be expressed by any simple or convenient mathematical formula, although numerous attempts have been made to do it.

One valuable general deduction, however, has been made from a study of these curves, by Ramsay and Shields, *viz.*, that a nearly constant numerical relation subsists, for any two given elements or compounds, between the *absolute* temperatures at which they have the same vapor tension. Expressing this in mathematical language, if two substances A and B have the same tension p at T_A and T_B, and the tension p' at T'_A and T'_B, then

$$\frac{T_A}{T_B} = \frac{T'_A}{T'_B}$$

This relation is not exactly accurate, but approximately so. For instance, if A is mercury and B water, the value of the ratio is

p = 34.4 mm. Hg.	T_A/T_B = 1.63
p = 157.2 mm. Hg.	T_A/T_B = 1.66
p = 761. mm. Hg.	T_A/T_B = 1.69
p = 2905. mm. Hg.	T_A/T_B = 1.74

If chemically like substances are compared, however, the rule seems to hold closer. It follows from the above relation, mathematically, that

$$\frac{T_A}{T'_A} = \frac{T_B}{T'_B}$$

which expresses the fact that the ratio of the absolute temperatures at which a given substance has the pressures p and p' is the same as the ratio of the absolute temperatures at which another substance has the same pressures p and p'. If the relation first given is true the other must be true, and *vice versa*. Nernst gives such a comparison for five methyl salts, in which the ratio was 1.115 to 1.113, and ten ethyl salts, in which it varied between 1.117 and 1.111. It therefore appears likely that when metals are similarly compared, a like uniformity of ratio may be found, reliable enough to serve as a guide towards a first approximation. Mercury, in fact, gives the ratio 1.117 for the same pressures used comparing the methyl and ethyl salts. We therefore feel considerable confidence in applying the same principle when comparing one metal with another metal.

It will be shown in the next section that the vapor tensions of most of the metals can be fairly accurately represented by the formula

$$\log p = -\frac{A}{T} + B.$$

For a second metal we would have

$$\log p = -\frac{A'}{T} + B'$$

The above discussed relations are accurately true if the two metals have the same values of B, that is, if $B = B'$. If B is not equal to B', the above relations will not be constant; conversely, if the above discussed relations are constant, then the $B's$ are all alike. This is strikingly true of the esters discussed by Nernst; it is only approximately true for water and mercury; it is probably nearly true for comparisons of the metals with each other.

(*B*) *Logarithm of Pressure Plotted Against Temperature.*

The form of the curve showing variation of vapor tension against temperature suggests investigating the variation of the logarithm of pressure against temperature, because of the asymptotic approach of the plain pressure curve towards zero at low temperatures and towards the vertical at high temperatures. In fact, an arithmetical analysis of the pressure curve confirms this by showing practically equal percentage (geometric) increases of the tensions for equal arithmetic increases of temperature. On plotting *log. p* for mercury against temperatures, the curve marked *B* in Fig. 1 is obtained. This is a slightly convex curve, with nearly equal curvature throughout, and therefore much better adapted for interpolation and extrapolation. These curves were used for some time, for plotting the vapor tensions of the metals, until a still more satisfactory relation was found.

(*C*) *Logarithm of Pressure Plotted Against Reciprocal of Temperature.*

A further study of the subject of pressures of liquids other than metals showed that when the logarithms of pressures were plotted against the reciprocals of the absolute temperatures, curves were obtained, with but slight curvature, approximating straight lines (see Curve C, Fig. 1). This is true of all such liquids and solids whose vapor tensions have been accurately determined. The curves are not straight lines, but only approximately so. A straight line relation would require $log.\ p. = -\frac{A}{T} + B$ and this does not accurately fit the tabulated values; but the formula of

Nernst ($log.\ p = \frac{A}{T} + 1.75\ log.\ T - CT + D$), with three constants instead of two, correlates the observed pressures and temperatures satisfactorily.

The vapor tension data for the metals, with the single exception of mercury, are not accurately known, and we may say of these experimental data that the formula $log.\ p = -\frac{A}{T} + B$ (wherein A and B are constants, and T the absolute temperature) fits them in general within the experimental errors of the determinations. In short, while a Nernst formula with three constants may be constructed for mercury, the simpler straight line formula is all that we are justified in constructing for the other metals. This simplifies very much the discussion of the vapor tensions of the metals, and enables us to make generalizations from very scanty data.

DISCUSSION OF THE STRAIGHT-LINE EQUATION.

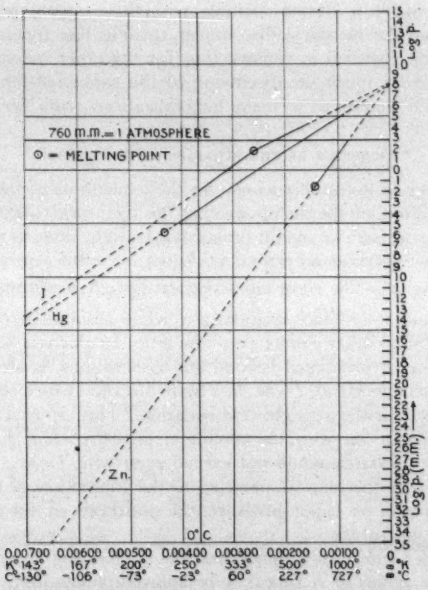
Plotting as accurately as we can the logarithms of the known vapor tensions of the metals against the reciprocals of the absolute temperatures, we obtain practically straight lines in all cases, within the experimental errors, as shown for iodine, mercury and zinc in Fig. 2. The right hand vertical line, representing $\frac{1}{T} = O$, really stands for infinite temperature, while absolute zero, $T = O$, would lie at an infinite distance to the left. In all cases, the vapor tension line, if prolonged beyond the observations, is seen to cut the right hand vertical, $T = \infty$, at a finite distance, which represents the value B in the straight-line equation. This, if exactly true, would indicate an absolute maximum pressure, ($log.\ p_{max} = B$), which the substance could not exceed even with $T = \infty$. This is an interesting speculation, pointing to the conception of an absolute maximum of vapor pressure, the antithesis of the absolute zero of temperature.

Another interesting generalization is that for the different metals the values of B appear to be approximately alike. Where we have sufficient data to draw the line (at least two observations of tensions at two different temperatures) the indicated values of B appear to be as follows:

Sodium	6.85
Copper	8.75
Zinc	8.17

Arsenic	8.65
Selenium	8.10
Silver	7.90
Cadmium	8.74
Mercury	7.73
Lead	8.00
Bismuth	7.45
Average	8.03

FIG. 2.



According to this observation, we may as a first approximation to a vapor tension curve write

$$\log. p = -\frac{A}{T} + 8.00$$

and if we have only one determination of vapor tension, at some temperature, we can determine A. If we have T for $p = 760$ mm. (1 atmosphere), as is often the case, then $A = 5.22\ T$. This is

frankly an approximate formula, since B is not properly a definite constant, but it is quite satisfactory to get a working formula which is approximately true, when only one value for the vapor tension is known.

The thermodynamics of this straight-line formula is interesting. The Clapeyron-Clausius equation gives the relation

$$L = RT^2 \frac{dp}{dT}$$

where L is the molecular latent heat of vaporization, T the absolute temperature, and R the gas constant, in calories.

Differentiating the straight-line equation for p and t we have

$$\frac{dp}{dT} = \frac{A}{mT^2}$$

where m is the modulus of the ordinary system of logarithms (0.4243).

Combining these, we have

$$\begin{aligned} L &= \frac{R}{m} \mathrm{A} \\ &= 4.57\, A \end{aligned}$$

It follows, that A furnishes us with the latent heat of vaporization, and that the straight-line equation makes this quantity a constant, at all temperatures. This is not a fact of nature, since we know that the latent heat of vaporization changes with the temperature, because of the difference of specific heats of the gaseous and liquid material, that it increases slowly going towards low pressures, and decreases fast at high pressures, becoming zero at the critical point. The straight line is therefore only a sector of a curve, drawn through two points of a curve which is convex towards the axis T, and which gives the average value of the latent heat of vaporization $(4.57A)$, for the temperature range between the points which have been used to determine the equation.

Since, however, the straight line does fit quite satisfactorily most of the actual determinations of vapor tensions of the metals which have been made, it follows that at these comparatively low pressures, far removed from the critical temperature, the latent heat of vaporization does not vary very much, is approximately constant, and can be derived from the vapor tension equation.

TROUTON'S RULE.

Trouton found that the molecular latent heat of vaporization at normal atmospheric pressure was a function of the absolute temperature of the normal boiling point. Numerically it averages 23 T. Nernst maintains that the 23 is not a constant, but varies somewhat with the temperature, being as low as 15 for substances boiling at very low temperatures and as high as 29 for those boiling at very high temperatures. It seems to be true, however, that for many substances boiling between 0° C. and 500° C., the constant is between 20 and 25, and averages 23. Substituting normal atmospheric pressure in the straight-line equation, and 23 T for 4.57 A, we would find that B was fixed, since

$$B = \log. p + \frac{A}{T} = 2.88 + \frac{23\,T}{4.57\,T} = 7.90$$

This is in pretty good agreement with the average value of B, 8.03, derived directly from the actual straight-line equation for ten different metals, on a previous page, using the experimental values. If we assume $B = 8.03$, and work the equation backwards, Trouton's constant would figure out 23.85. I have concluded to use the values 23 and 7.90 for low boiling-point metals (500°–1500° C.), and 25 and 8.4 for high boiling-point metals (over 1500° C.).

RICHARDS' RULE.

A rule similar to Trouton's was discovered by the writer concerning the latent heat of fusion, *viz.*, the molecular latent heat of fusion is approximately 2.1 T, where T is the absolute melting point. This observation is useful in deriving the straight-line relation for the sublimation of a solid metal below its melting point.

$$\log. p = \frac{A'}{T} + B'$$

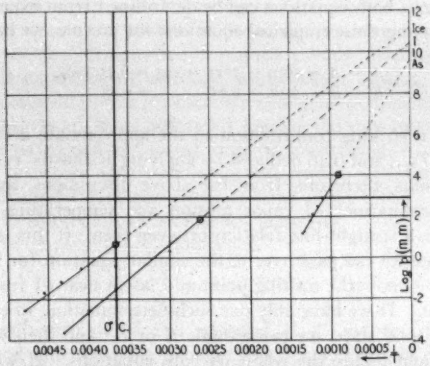
In this equation, 4.57 A' is the latent heat of sublimation, and a study of the rather scanty data on the vapor tension of solid substances shows that such an equation fits satisfactorily the experimental data. Fig. 3 shows this for ice, iodine and arsenic.

Since the latent heat of sublimation equals the sum of the latent heat of vaporization of the liquid and the latent heat of fusion, then

$$4.57\,A' = 4.57\,A + L \text{ fusion}$$
$$A' = A + \frac{L \text{ fusion}}{4.57}$$

If the latent heat of fusion of a metal is known, we express

FIG. 3.



it per molecular (= atomic) weight, divide by 4.57 and add the quotient to A to get A'.

Since at the melting point the vapor tensions of the solid and the liquid are alike, if we substitute $T_{m.p.}$ in the two equations under consideration, we have

$$log.\ p_{m.p.} = -\frac{A'}{T_{m.p}} + B' = -\frac{A}{T_{m.p}} + B$$

Whence

$$B' = \frac{A' - A}{T_{m.p}} + B$$

$$= B + \frac{L \text{ fusion}}{4.57\ T_{m.p}}$$

If the latent heat of fusion is known, B' can thus be calculated, and we have the complete vapor tension line for the solid state.

If the latent heat of fusion is not known, we may put it, as a first approximation, as equal to $2.1\ T_{m.p.}$ We then have

$$A' = A + \frac{2.1\ T_{m.p.}}{4.57} = A + 0.46\ T_{m.p.}$$

$$B' = B + \frac{2.1\ T_{m.p.}}{4.57\ T_{m.p.}} = B + 0.46$$

Richards' rule would therefore enable us to pass from the vapor tension equation for the liquid state to that for the solid state, and *vice versa*, if merely the melting point is known, without knowing experimentally the latent heat of fusion. In a few cases, *e.g.*, arsenic, both equations can be determined from experimental data. Taking these empirical equations for arsenic, we have

$$A' - A = 5610 - 5115 = 495 = 0.45\ T_{m.p.}$$
$$B' - B = 9.10 - 8.65 = 0.45$$

which is a striking confirmation of the approximate accuracy of the 0.46 $T_{m.p.}$ and 0.46 deduced by applying Richards' rule.

It results, therefore, from the above discussions, that given two determinations of vapor tension and temperature, we can determine a straight-line relation between them; if this is for the liquid state we can pass over to the similar equation for the solid state if we know the melting point and latent heat of fusion, and *vice versa*. If we have only one such determination, in either the liquid or solid state, we can assume B or B', and then work out A or A' and thence the whole of both equations. If we do not know the latent heat of fusion, it may be assumed as equal to 2.1 $T_{m.p.}$, and then the complete scheme worked out. Finally, if we do not have a single vapor tension determination, but know the latent heat of vaporization (of the liquid) or the latent heat of sublimation (of the solid) we could work out a first approximation to the vapor tension equation for the liquid or the solid state; if we know the melting point, we can pass from one to the calculation of the other.

Table I gives the vapor tensions of the metals, and a few non-metals, as far as their straight-line equations can be determined, either from the experimental data, or by assumption of values of the constant B. These data are in many cases only first approximations, but they are also, in not a few cases, the first attempts to get an idea of the order of magnitude of these vapor tensions, and therefore deserve some serious consideration even if they cannot be considered as accurate.

Table II gives several estimated and a few observed values of the latent heats of vaporization of some elements, mostly metals. Since the experimental values are mostly lacking for the metals, the calculated or estimated values, using Trouton's rule, are of considerable value as first approximations, even though we know they cannot be strictly accurate.

THE TRUE VAPOR TENSION CURVE.

From the experimental data regarding the vapor pressures of the metals we are not justified in deducing formulas of more than two terms—the straight-line formulas already discussed (with the single exception of mercury, whose vapor tension has been minutely studied)—yet for mercury and some non-metals, whose vapor tensions are more accurately known, the true vapor tension curve, as developed by Nernst, may be constructed.

It is therefore *apropos* to state this true curve, in order that it may be used for mercury and for any other metal for which the experimental data are sufficiently accurate.

The more accurate relationship is

$$log.\ p = -\frac{A}{T} + 1.75\ log.\ T - C\,T + D$$

The three constants of this equation A, C and D are not the same as A and B of the straight-line formula above discussed, but $4.57\ A$ of this equation represents the latent heat of vaporization of the substance for $T = O$; a wholly theoretical quantity.

The formula requires for its determination only three observations of vapor tensions at three different temperatures. They must be accurate enough to fix the form of the curve and the three constants.

The differentiation of this formula for dp, and substitution of this in the Clausius expression for L, the latent heat of vaporization, gives

$$L = 4.57\ [A + 0.743\ T - C\,T^2]$$

This formula is true only for moderate pressures, far removed from the critical temperature, where the volume of the liquid is negligible in comparison with the volume of the gas which it forms. At high pressures, where the volume (and density) of the vapor approximates the volume (and density) of the liquid, the formula is not accurate for two reasons: (1) The density of

TABLE I.

Vapor Tensions of the Metals.

In the Solid and Liquid States, at Their Melting Points, and at 0° C. p = mm. Hg., T = Degrees Absolute = °K.

	Solid $\log. p = -\frac{A'}{T} + B'$		At 0° C. mm. Hg.	At *M. P.* mm. Hg.	Liquid $\log. p = -\frac{A}{T} + B$	
	A'	B'			A	B
H_2	.....	....	.....	.....	51.5	5.4
Br_2	.....	....	66	45	1635	7.8
I_2	3458	10.43	2×10^{-2}	89	2390	8.1
P_4	2260	7.34	0.115	1.63	2160	7.0
Hg	3170	8.26	0.0002	5.13×10^{-6}	3069	7.75
S_8	4140	9.15	1×10^{-6}	0.028	3745	8.1
As_4	5610	9.10	2.8×10^{-21}	10,000	5115	8.65
Se_2	5250	8.56	2.1×10^{-11}	0.71	5025	8.1
Cs	4900	8.35	2.5×10^{-10}	1.2×10^{-5}	4760	7.92
K	5300	8.26	7.1×10^{-12}	2.25×10^{-5}	5190	7.92
Rb	5040	8.28	6.7×10^{-11}	1.5×10^{-5}	4890	7.90
Cd	6470	9.28	3.8×10^{-15}	2.6×10^{-2}	6151	8.74
Na	4700	7.30	8.1×10^{-9}	3.55×10^{-6}	4565	6.85
Zn	6685	8.63	1.03×10^{-16}	9.3×10^{-2}	6365	8.17
Mg	8060	8.81	5.25×10^{-20}	1.15	7690	8.4
Te_2	10,230	9.84	8.1×10^{-22}	6.3×10^{-5}	9180	8.4
Bi	10,000	8.45	6.6×10^{-19}	$1. \times 10^{-10}$	9460	7.45
Sb	10,850	9.58	6.5×10^{-21}	3.55×10^{-3}	9790	8.4
Tl	10,260	8.5	8.3×10^{-20}	4.7×10^{-10}	9940	7.92
Li	8900	8.38	$6. \times 10^{-25}$	4.9×10^{-12}	8690	7.92
Pb	9744	8.41	4.9×10^{-28}	1.5×10^{-8}	9500	8.0
Mn	12,650	8.85	3.2×10^{-28}	1.98	11,195	8.4
Ag	12,180	8.36	5.6×10^{-37}	3.2×10^{-2}	11,600	7.9
Ni	14,245	8.90	5.25×10^{-44}	4.36	13,375	8.4
Al	14,190	8.98	1.0×10^{-42}	5.25×10^{-7}	13,650	8.4
Si_2	15,530	9.0	8.0×10^{-47}	1.32	14,200	8.4
Cr	14,460	8.86	7.8×10^{-43}	4.47	13,650	8.4
Sn	14,420	9.1	5.6×10^{-44}	6.3×10^{-20}	13,930	8.4
Cu	15,765	9.17	2.6×10^{-49}	3.5×10^{-3}	15,160	8.75
Fe	15,840	8.84	6.9×10^{-50}	1.20	15,030	8.4
Pt	16,250	9.0	3.0×10^{-51}	9.55	15,040	8.4
Ti	16,090	8.85	8.3×10^{-49}	11.75	15,170	8.4
Rh	16,500	8.94	3.2×10^{-52}	38	15,300	8.4
Ru	16,450	8.86	4.0×10^{-52}	28.8	15,420	8.4
Au	16,175	8.93	4.8×10^{-51}	6.8×10^{-4}	15,470	8.4
Pd	16,340	8.85	1.4×10^{-60}	0.78	15,500	8.4
Ir	16,670	8.81	5.6×10^{-58}	302	15,580	8.4
Os	16,880	8.81	9.6×10^{-54}	97.7	15,870	8.4
U	17,975	8.85	1.0×10^{-57}	5.5×10^{-6}	17,400	8.4
Mo	22,650	8.85	7.6×10^{-75}	4.9	21,380	8.4
B_2	21,230	8.36	3.9×10^{-76}	5.0	19,950	7.92
C_2	24,300	9.0	1.0×10^{-80}	6,310	22,195	8.5
W	31,670	8.86	7.4×10^{-108}	1.3	30,000	8.4

TABLE II.

Latent Heats of Vaporization.

	B. P. C.°	B. P. K.°	Trouton's Rule 23 T (Molecular)	Calc. by Trouton's Rule (per Kg.)	Observed (per Kg.)	Calc. from Vapor Tension Curve (per Kg.)
H_2	—253	20	460	230	....	118
N_2	—196	77	1771	63	50	54
O_2	—188	85	1955	61	58	52
Cl_2	—22	251	5773	81	67	72
Br_2	58	331	7613	48	46	....
I_2	174	447	10,280	27	24	....
P_4	287	560	12,880	138	130	....
Hg	357	630	14,490	72	68	67
S_8	444	717	16,390	64	72	....
As_4	450	723	16,625	74	....	....
As_2	616	889	[22,225]	99	....	114
Se_2	690	963	22,150	94	....	97
K	757	1030	23,690	607	....	....
Cd	778	1051	24,170	216	181?	251
Na	877	1150	26,450	1150	....	905
Zn	930	1203	27,670	426	366?	446
Mg	1120	1393	32,040	1335	1700?	1443
Te_2	1390	1663	38,250	151	....	166
Bi	1435	1708	39,280	189	162?	208
Sb_2	1500	1773	41,480	115	....	124
Tl	1700	1973	45,380	222	....	....
Li	1450	1723	39,630	5,660	....	....
Pb	1580	1853	41,820	202	....	209
Mn	1900	2173	49,980	909	....	995
Ag	2040	2313	53,200	493	....	490
Ni	2150	2423	55,730	953	....	1042
Al	2200	2473	56,880	2107	....	2305
Si_2	2200	2473	56,880	1015	1262	1153
Cr	2200	2473	56,880	1094	....	1197
Sn	2250	2523	58,030	492	....	538
Cu	2310	2583	59,410	934	....	1087
Fe	2450	2723	62,630	1118	....	1224
Pt	2450	2723	62,630	318	....	351
Ti	2475	2748	63,200	1317	....	1431
Rh	2500	2773	63,780	619	....	677
Ru	2515	2788	64,120	629	....	689
Au	2530	2803	64,470	327	....	358
Pd	2535	2808	64,580	606	....	667
Ir	2545	2818	64,810	336	....	368
Os	2600	2873	66,080	346	....	379
U	2900	3173	72,980	305	....	333
Mo	3600	3873	89,780	935	....	1015
B_2	3700	3973	91,380	4155	....	....
C_2	3700	3973	99,125	4140	....	....
W	5200	5473	125,880	684	....	....

the gas no longer obeys Boyle's law; (2) the density of the liquid increases because of the great pressure. The formula is very applicable, however, to all ordinary temperatures and pressures. Worked out for mercury, at 760 mm. pressure, it gives 66.8 calories per gram, whereas experiment shows 67.8 cal.; for 0° C. it gives 77.1 cal.

PRACTICAL APPLICATIONS.

Distillation of Metals.—Some metals are obtained entirely by distillation from their ores, escaping from the reduction furnaces entirely as vapor. Such is the case with mercury, cadmium and zinc. In these cases, the useful work performed by the furnace is not entirely known until the heat in the vapor of the metals is known. For mercury this item is not large, but it is considerable for cadmium and still greater for zinc. In fact, for zinc it forms a material part, some 25 per cent., of the total thermal work done in the furnace. It is only recently that the latent heat of vaporization of zinc has been experimentally determined; up to that time we could use only the value derived from the vapor tension curve or by use of Trouton's rule. In electric furnaces large quantities of high boiling-point metals are volatilized, and thus consume a large proportion of the expensive electric power required to run them; a silicon furnace is a good example of this, where as much as 25 per cent. of the reduced silicon may be vaporized out of the furnace. We can get a first approximation to these losses of power by studying the vapor pressures of these metals and thus their latent heats of vaporization.

According to the principle of partial pressures of the constituent gases in mixtures, the metallic vapors may be at small fractions of atmospheric pressure when mixed with other inert gases. The problem of condensing these vapors is then complicated by the fact that they do not commence to condense at their normal boiling points, but only at much lower temperatures corresponding to their partial pressures in the gas mixture. This dew point, as it may be properly called (since the principle involved is exactly similar to the deposition of water as condensed moisture, or dew, from moist air) is often at unexpectedly low temperatures, and the more dilute the gas mixture the lower the condensing temperature. Gases from the mercury furnace are sometimes only 1 per cent. mercury vapor, and their dew point may be 150° to 200° C. instead of 357°, the condensing point of pure

mercury vapor. The whole phenomena of condensation of metallic vapors, including the heat liberated in the condensation as well as the per cent. of the metallic vapor condensed, depend for their study and investigation on the correct use of vapor tension data.

When zinc-lead-silver-gold skums from the Parkes process are distilled, the first zinc coming off is nearly pure, but as the zinc present in the alloy decreases a higher and higher temperature is required to drive it off, at atmospheric pressure, until the last part of the zinc comes off only at the maximum temperature of the furnace, some 1300° C. Successively larger amounts of lead, silver and gold come over the higher the temperature and the lower the proportion of zinc in the alloy. All these phenomena are governed by the vapor tensions of the respective metals, and the principle that they exert fractions of their maximum tensions proportional to the relative *molecular* proportions of each present in the alloy. Interesting and practically valuable calculations can thus be made. The temperature necessary to reach in order to attain any given purity of the residual alloy or metal can be thus calculated, as also the composition of the condensed vapors. The composition of the condensate is very different from that of the residuum; the former approximates to equal molecular weights (atomic weights) of the metals present; the latter to one single metal (the least volatile), almost pure, with decreasing amounts of the impurities according to their greater volatilities.

Zinc Losses in Brass Melting.—Considerable zinc is lost in making and melting brass. The normal boiling point of zinc is 930° C., yet brass is usually made and cast at 1000° to 1200° C. We are spared the loss of all the zinc by two facts: (1) The molecular (atomic) proportion of the zinc present is 15 to 30 per cent., which means that at any given temperature the zinc in this alloy can exert only 15 to 30 per cent. of the maximum vapor tension of pure zinc at that temperature; (2) the copper and zinc unite with some energy, and the energy of that combination also retards the volatilization of the zinc and lowers still more its vapor pressure. Owing to these two circumstances, the vapor tension of zinc from brass is usually less than atmospheric tension at operating temperatures, and therefore the losses are not excessive.

If the vapor tension of pure zinc is

$$\log. p = -\frac{6365}{T} + 8.17$$

then if the atomic fraction of zinc present in the alloy is f, the vapor tension relation becomes

$$log.\ p + log.\ f = -\frac{6375}{T} + 8.17$$

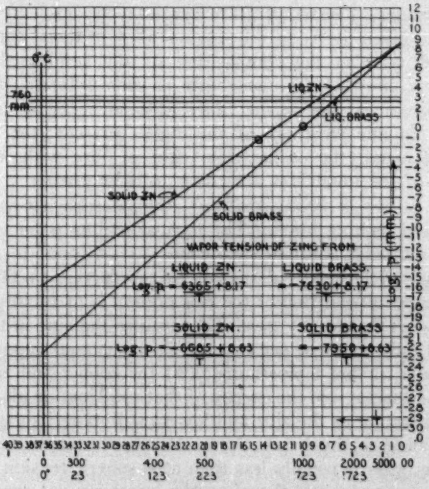
Further, if the zinc atom unites with copper with evolution of the energy Q ($Cu_2, Zn = Q$), this energy must be added to the work done in the vaporization of the zinc, and we have

$$log.\ p + log.\ f = -\frac{6365 + Q/4.57}{T} + 8.17$$

as the complete expression for the vapor tension of zinc from brass.

This equation, if Q were known for different grades of brass, would be of considerable use in the scientific development of the brass industry (Fig. 4).

FIG. 4.



Loss of Metals as Fume.—This subject is of great importance with metals of high value, such as silver, gold and platinum, where comparatively small losses in weight represent large losses

in value. Even in such a simple operation as melting silver, if the heating is done by a flame coming in contact with the metal, the vaporization losses even from the *solid* metal, before it melts, may be considerable. This is a phenomenon strictly analogous to the vaporization (sublimation) of ice in a current of dry air at temperatures below the freezing point. To estimate its amount, we must know the vapor tension of solid silver below its melting point. While melting, and at higher temperatures, considerably more silver is volatilized, and the vapor tension curve enables us to calculate the amounts for different temperatures of the gases in contact with it.

One firm, using the tabulated vapor tensions, and measuring carefully the temperatures and amounts of the gases going through its furnaces, calculated that it was vaporizing about $30,000 worth of silver per year. On the strength of this calculation they put in a Cottrell electrostatic precipitation plant (costing $25,000), and in the first year of its operation collected just $30,000 worth of silver from the fume.

Sherardizing and Calorizing.—These are processes which coat iron or other metals with zinc or aluminum respectively, by heating the iron objects to a moderate temperature, below the respective melting points of zinc and aluminum, until their surface has absorbed the desired amount of coating.

Sherardizing was invented first, and has already come into large use as a competitor of ordinary galvanizing. The zinc soaks into the surface of the iron like ink into blotting paper, adding to the weight of the object but not to its external dimensions, and leaving perfectly sharp and unchanged screw threads or other superficial characteristics. The whole operation depends on the formation of zinc vapor from the solid zinc dust and its absorption by the iron. The vapor tension curve of solid zinc, at the temperatures used, gives a quantitative explanation of the rate of absorption with change of temperature, and therefore serves as a practical guide in studying and operating the process.

Calorizing is operated at still lower metallic vapor pressures, because of the high normal boiling point of aluminum, yet while about 0.1 mm. (Hg) pressure of zinc vapor effects Sherardizing, not over 0.000001 mm. (Hg) of aluminum vapor effects calorizing.

A study of the vapor tensions of metals at their melting points

will show which are best able to act like zinc and aluminum in a similar manner, for metal plating purposes.

Vapor Losses During Electrolysis.—We will consider finally the question of losses of metal at the cathode during electrolysis of melted salts, using melted metal as cathode. The production of aluminum is a good example. Here, the ampere efficiency of metal obtained is 75 to 90 per cent. of the metal actually deposited; the loss is due to the phenomenon of metallic mist or fog or vapor, called *metallische Schleier* by Lorenz, of Zurich, who investigated it most fully.

There seems to be strong evidence for believing that these large percentage losses are connected directly with the vapor tension of the molten metal. Lorenz was handicapped in his discussion by very inadequate data as to the vapor tensions of these metals at the temperatures in question, which are not far above their melting points.

We may indulge the hope that the approximate values of the vapor tensions deduced by us may be of use also in this field, in helping to a better understanding of these losses and possibly in helping to reduce or to obviate them.

"Vest-pocket" Camera for Commercial Photography. ANON. (*British Journal of Photography*, vol. lxvi, No. 3070, p. 109, March 7, 1919.)—There are occasions when a high-grade small camera, far from being a toy, may be of very real service to the photographer placed in exceptional circumstances. The fact that these instruments are fitted with lenses of short focus and wide aperture, and thus give good definition over many varied planes of distance without recourse to stopping down may often be of real service. A case in illustration of this point was told some time ago by a commercial worker. He was commissioned to make a series of pictures of certain pieces of machinery in a factory which was rather poorly lighted. As the work would have necessitated the use of a lens well stopped down in order to gain the required definition, and as the stoppage of the machinery was an important factor, the operator took with him a vest-pocket camera. This he found gave all the definition required, and fine definition without stopping down the lens. The result was that the pictures were taken in a very short time, as the worker was enabled to use the lens working at f/6 instead of one stopped down to f/22. Enlarged prints were made that gave the customer entire satisfaction.

HOW THE NITROGEN PROBLEM HAS BEEN SOLVED.* †

BY

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III. THE ABSORPTION OF NITROGEN BY CARBIDES; THE CYANAMIDE PROCESS.

In 1894 the attention of the technical world was focussed upon the invention of Moissan and Wilson, which led to the manufacture of calcium carbide in the electric furnace on a large scale. A short time afterwards, Frank and Caro made the discovery that while barium carbide could readily be made to combine with atmospheric nitrogen at high temperatures to form barium cyanide, but small quantities of cyanide could be formed with calcium carbide under the same conditions, notwithstanding the fact that there was apparently a large absorption of nitrogen. This striking result led to a closer examination of the reaction product, and it was found that most of the nitrogen absorbed by the carbide had been converted into calcium cyanamide. From a technical standpoint, the absorption of nitrogen by calcium carbide at high temperatures is of the greatest significance, and constitutes one of the most important means for the fixation of atmospheric nitrogen.

OUTLINE OF THE PRINCIPLES UNDERLYING THE FORMATION OF CALCIUM CYANAMIDE FROM CALCIUM CARBIDE AND ATMOSPHERIC NITROGEN.

Although the reaction between calcium carbide and nitrogen is usually expressed by the simple reversible equation:

$$(12)\quad CaC_2 + N_2 \rightleftarrows CaCN_2 + C,$$

in reality it is so complicated that up to the present all attempts to establish its equilibrium constants have been unsuccessful. If

* Communicated by Professor Creighton.

† Continued from page 408, Vol. 187, April, 1919.

calcium carbide, calcium cyanamide and carbon are regarded as solid phases, the system should be monovariant, and there should be a definite pressure corresponding to a given temperature. Should the pressure exceed this equilibrium value, then nitrogen must be absorbed by the carbide, while if the pressure should be less than this value, then calcium cyanamide must react with the carbon to re-form calcium carbide and nitrogen.

Attempts to measure the equilibrium of the reaction have produced very conflicting results. Thus, the equilibrium temperature corresponding to a pressure of one atmosphere is given as 1700° C. by Thompon and Lombard, as 1360° C. by Caro, and as 1100° by Matignon. This lack of agreement has been ascribed to a number of different causes, among which may be mentioned the chemical inertness of nitrogen; the impurities present which probably take part in the reaction; the disturbance of the equilibrium caused by sublimation of the calcium cyanamide; and still more fundamental, the fact that probably during the reaction calcium carbide dissociates into carbon and a lower carbide.

The azotization of calcium carbide is a strongly exothermic reaction. So much heat is liberated during the initial stages of the reaction that the reaction mass is raised to between 1000° C. and 1100° C., the temperature necessary for satisfactory azotization.

The rate at which nitrogen is absorbed by commercial calcium carbide varies with the temperature at which azotization takes place, a temperature of at least 1000° C. being necessary for rapid and complete azotization. Below this temperature, the absorption of nitrogen is limited and takes place slowly. The influence of temperature on the rate of absorption is illustrated graphically by the full curves in Fig. 15, for nitrogen under a water pressure of 132 mm. The rate of azotization also increases with the pressure up to about two atmospheres, but further increase in pressure produces little change in the rate at which the gas is absorbed.

Moissan has shown that pure calcium carbide is quite inert towards nitrogen at a temperature of 1200° C. The ease with which the commercial carbide absorbs nitrogen at this temperature is due to the presence of 10 to 15 per cent. of lime and other impurities which act as catalysts.

It has been found that if certain substances are admixed with

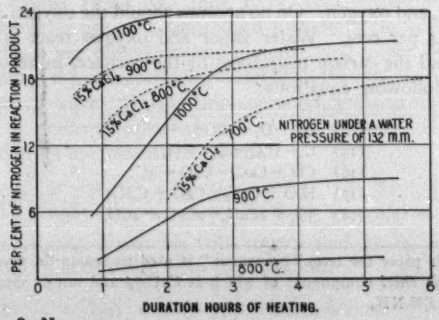
commercial calcium carbide, the rate of azotization is markedly increased, and the minimum initial reaction temperature is lowered. For metals of the same periodic group, the acceleration is greater the lower the atomic weight. Of the many addition substances studied, the most effective is calcium chloride, as is shown by the data contained in Table VIII, in which is given the per cent. of nitrogen absorbed in two hours at 800.°

TABLE VIII.

Addition Substance.	Per cent. nitrogen absorbed.
None	3.2
10 per cent. CaO	4.0
10 per cent. Na_2CO_3	8.5
10 per cent. NaCl	13
10 per cent. $CaCl_2$	22

Calcium chloride lowers the reaction temperature to such an extent that a rapid absorption of nitrogen takes place at temperatures from 700° C. upwards. The rate of absorption increases with the content of the chloride up to 30 per cent., although its effect becomes less marked as the percentage increases. With calcium fluoride the reaction temperature is not brought so low as in the case of the chloride, and an addition of from 2 to 5 per cent. is most favorable. The rate of azotization of calcium carbide at different temperatures in the presence of 15 per cent. of calcium chloride is shown by the broken curves in Fig. 15.

FIG. 15.



The ultimate cause of the increased azotization of calcium carbide by these addition substances (including the lime always present in the commercial carbide) is probably due to their assisting the reaction by the removal of the film of calcium cyanamide from the carbide, and to their softening the reaction mass, thus increasing its power of taking up nitrogen. The immediate cause is more obscure, but is probably related to the rate of decomposition of the carbide into carbon and a sub-carbide,

$$(13)\quad CaC_2 \rightleftarrows CaC + C,$$

and the absorption of nitrogen by the latter,

$$(13a)\quad CaC + N_2 \rightleftarrows CaCN_2.$$

THE TECHNICAL PRODUCTION OF CYANAMIDE.*

The calcium carbide employed in the manufacture of cyanamide is prepared from lime and coke in the electric furnace, and is usually about 80 per cent. pure. After cooling, the carbide is ground in air-tight apparatus filled with nitrogen, so that it passes a hundred-mesh screen. As carbide of this fineness is almost as explosive as low-grade dynamite when exposed to the atmosphere on a damp day, the operation of grinding presents a problem.

The nitrogen used in the manufacture of cyanamide is obtained at the present time either by the fractional distillation of liquid air, or by the copper oxide process. As the gas must be of a high degree of purity, it has to be freed from water vapor, the oxides of carbon, and oxygen. On no account should the oxygen present exceed 0.4 per cent. Water vapor and oxygen react with the carbide and the carbon resistances of the furnace, in accordance with the following equations:

$$(14)\quad 2C + O_2 = 2CO;$$
$$(15)\quad C + H_2O = CO + H_2;$$
$$(16)\quad CO + CaC_2 = CaO + 3C;$$
$$(17)\quad H_2O + CaC_2 = CaO + C_2H_2;$$
$$(18)\quad 3O_2 + 2CaC_2 = 2CaO + 4CO.$$

* In this paper the term "cyanamide" is used to denote the commercial product, the chief component of which is $CaCN_2$, and not to denote the compound $CN.NH_2$.

The finely ground carbide is transferred to iron retorts having a capacity of from one-half to two and one-half tons. By employing small units a uniform temperature and, therefore, a more reliable product, can be obtained. The retorts are next placed in the "furnace," consisting of a gas-tight, horizontal channel, the roof of which is removable to allow of the handling of the retorts. Pure nitrogen is then admitted into the channel of the furnace under a pressure slightly in excess of one atmosphere, so as to overcome any tendency of air to enter.

The retorts are heated electrically by means of carbon resistances. Each retort contains a central carbon rod, or several connected in series. When the retorts are in position, the resistances are connected electrically to suitable permanent terminals in the furnace. With the electric method of heating, difficulties arising from strong sintering of the material and its adhesion to the walls of the retort are avoided.

After all the air has been expelled from the retorts, the electric current is turned on. Each retort requires from 65 to 75 volts. It is probable that a number of units are connected in parallel, and that a low current, *e.g.*, 20 amperes, is employed. The retorts are heated for thirty or forty hours, during which time the temperature in the outermost layers of the reaction mass rises to about 1000° C. The current is then interrupted and the reaction allowed to complete itself, the end being indicated by the pressure registered by a manometer in the nitrogen pipe line.

The crude cyanamide when taken from the furnace usually contains 63 per cent. calcium cyanamide, corresponding to 22 per cent. nitrogen, 12 per cent. lime, 12 per cent. carbon in the form of graphite, 1 per cent. unazotized carbide, 1 per cent. calcium sulphide, 2 per cent. iron and alumina, and 2 per cent. silica. On cooling, the cyanamide is ground in an atmosphere of nitrogen to a fine powder. During this operation, great precautions are taken to prevent explosions due to the presence of acetylene derived from the unazotized carbide.

PRODUCTION OF AMMONIA FROM CYANAMIDE.

On treating cyanamide with superheated steam, ammonia is produced in accordance with the equation:

$$(19)\quad CaCN_2 + 3H_2O = CaCO_3 + 2NH_3.$$

Under proper conditions the reaction is almost quantitative. The rate at which ammonia is formed increases with temperature, as is shown by the data in Table IX.

TABLE IX.

Temperature ° C.	Per cent. nitrogen converted into ammonia at the end of:	
	15 minutes.	45 minutes.
120°	11.3	31
160°	45.8	83.7
180°	75.2	....

The reaction follows the monomolecular equation, the velocity constant at different temperatures having the following values: 0.00362 at 120° C., 0.0046 at 130° C., 0.00687 at 140° C., 0.0111 at 150° C., 0.0177 at 160° C., 0.027 at 170° C. and 0.0403 at 180° C.

The reaction is exothermic, and the heat developed is sufficient to cause the process to proceed of itself at a high velocity, when once it has started. In order to take advantage of this heat development, the reaction is carried out in steel autoclaves, 8 feet in diameter and 20 feet high, capable of operating under a working pressure of 300 pounds per square inch. In each autoclave is placed about 12,000 pounds of mother liquor derived from a previous operation (fresh water to start), and the finely ground cyanamide slowly fed into this liquor under continuous agitation by a powerful stirring apparatus with which each autoclave is provided. Any acetylene evolved during this operation is removed by a suitable ventilating system. In order to insure thorough incorporation of the cyanamide, the charging of the autoclaves is usually carried out over a period of an hour. Lime and soda are next added. These substances increase the efficiency of the ammonia evolution, principally through the prevention of the formation of polymeric forms of cyanamide compounds which are difficult to transform into ammonia. The autoclaves are then closed and superheated steam admitted until the pressure gauge registers 3 or 4 atmospheres. The temperature is then sufficiently high to start the reaction at a fair rate of speed, after which it proceeds of itself. As the temperature rises the gas pressure is relieved by means of valves through which the gas is discharged, the rate being so regulated as to maintain a constant pressure on

the ammonia line. The evolution of ammonia usually continues for about one and one-half hours. While nearly all of the cyanamide is decomposed during this operation, the steaming is usually repeated a second, and even a third time.

The ammonia-steam mixture which comes from the autoclaves is passed through a simple rectifying column provided with a dephlegmator and condenser, from which is obtained ammonia, saturated with water vapor, having a very high degree of purity.

PRODUCTION, ENERGY REQUIREMENTS AND COSTS.

During the past few years the production of cyanamide has increased very rapidly, furnishing in 1918 about one-fifth of the world's fixed nitrogen. The present annual producing capacity of different countries is as follows [5]:

Germany	500,000 Tons
France	300,000 Tons
United States (Muscle Shoals)	220,000 Tons
Norway and Sweden	220,000 Tons
Canada (Niagara Falls)	64,000 Tons
Italy	60,000 Tons
Japan	50,000 Tons

Aside from the preparation of nitrogen, the electrical energy requirements in the manufacture of cyanamide amount to 16.6 kilowatt hours per kilogram of nitrogen fixed, or to 1 kilowatt hour per 100 grams of cyanamide produced. The cost of conversion of cyanamide to ammonia has been estimated (on a pre-war basis) at one and one-half cents per pound of ammonia, and the total cost of ammonia by the cyanamide process, with power at $8 per horse-power year, at one to two cents more than by the Haber process.

ADVANTAGES AND DISADVANTAGES.

The chief advantages of the fixation of atmospheric nitrogen by carbides, as represented by the cyanamide process, are:

1. Moderate power requirements.
2. Easy transportability.
3. Product may be used as a fertilizer or for the production of ammonia of a very high degree of purity.

The chief disadvantages of the process are:

1. Number of operations involved, especially if it is required

[5] The writer wishes to acknowledge his indebtedness to Mr. E. J. Pranke, of the American Cyanamide Company, for the figures.

to produce nitric acid, *viz.*, production of carbide, production of pure nitrogen, production of cyanamide, decomposition of cyanamide to ammonia, oxidation of ammonia, absorption of nitrous gases, and the concentration of dilute nitric acid.

2. Process is extremely dusty and disagreeable.
3. Large labor factor involved.
4. Comparatively high cost.

IV. THE ABSORPTION OF NITROGEN BY METALS IN THE FORM OF NITRIDES.

Since many metals, such as titanium, aluminium, lithium, magnesium, etc., readily combine with nitrogen to form nitrides from which ammonia is easily obtained, this class of compounds has been extensively studied during recent years, with a view towards determining whether they could be employed for the commercial fixation of atmospheric nitrogen.

The normal nitride of titanium, TiN_2, on being heated in a current of hydrogen, yields nearly one-half of its nitrogen in the form of ammonia. The residual lower nitride, TiN, on being heated in an atmosphere of nitrogen is converted back into the normal nitride. Repeated attempts have been made in France to build up an industrial process for the manufacture of ammonia on the basis of this reaction, but without success. Some years ago, H. B. Landmark claimed to have perfected a continuous process for the manufacture of ammonia from this nitride, based upon the reaction expressed by the equation:

$$(20) \quad 2TiN_2 + 3C + 3H_2O \rightleftarrows 2TiN + 3CO + 2NH_3.$$

Steam is passed over a heated mixture of the nitride and carbon. By substituting a current of nitrogen for steam the normal nitride is regenerated; by employing a current of steam in place of the nitrogen, the operation becomes continuous, requiring from time to time a renewal of the supply of carbon. Essentially the titanium acts as a catalytic agent.

Ottokar Serpek was the first to recognize the possibility of applying the reaction between aluminium and nitrogen to the fixation of atmospheric nitrogen. The manufacture of aluminium nitride has received considerable attention because of the ease with which it can be converted into ammonia, and because of the possible importance for the aluminium industry of the alumina obtained as a by-product. Indeed this is the only process depend-

ing on the formation of a metallic nitride which, at the present time, seems to offer prospects of technical success for the fixation of atmospheric nitrogen. Though the process was in operation in a small way at Saint Jean de Maurienne, in Savoy, and two large semi-commercial installations are at present being tested in this country, at the present time it must be regarded as an unproven process.

THE TECHNICAL PRODUCTION OF ALUMINIUM NITRIDE BY THE SERPEK PROCESS.

In the Serpek process, aluminium nitride is prepared from bauxite and carbon, the reaction being expressed by the equation:

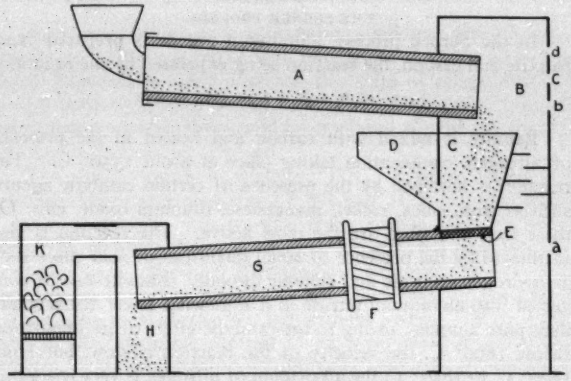
$$(21) \quad Al_2O_3 + 3C + N_2 = 2AlN + 3CO.$$

Bauxite is mixed with carbon and heated in the presence of nitrogen, combination taking place at about 1550° C. The reaction is hastened by the presence of certain catalytic agents, such as iron, silica, nickel, manganese, titanium oxide, etc. Of these iron and silica are the most active. The reaction is also facilitated by the presence of small quantities of acid gases such as hydrogen chloride and sulphur dioxide. Bauxite can be converted into aluminium nitride at a somewhat lower temperature than pure alumina, owing to the catalytic effect of its impurities. Below 1800° C. the velocity of the reaction is slow, but from 1800° C. to 1850° C. the absorption of nitrogen is very energetic, and in five minutes the alumina is completely converted into nearly chemically pure nitride. Smaller yields are obtained at higher temperatures, and above 2000° C. the formation of nitride practically ceases, owing to decomposition. Recently, Serpek claims to have reduced the time of reaction to a fraction of a second by suitable control of the reaction mixture and the nitrogen supply.

The apparatus employed by Serpek for the manufacture of aluminium nitride is shown diagramatically in Fig. 16. It consists of two superposed rotating cylindrical kilns, slightly inclined to one another and rotating in opposite directions. Each of these kilns is 10 metres long. Into the upper one, A, the powdered bauxite is introduced, which in its descent is calcined and heated to a temperature of 1400° C. by the passage of hot gases over it. On leaving the lower end of the kiln, the calcined bauxite falls into the hopper, C, in the vertical chamber, B, where it is mixed with the proper amount of carbon (coal) introduced at D. The

mixture then enters the upper end of the nitriding kiln, G, through the openings, E, and in its descent passes through the electrically heated region, F. Here the mixture is heated to the reaction temperature 1800° C.–1900° C. The kiln, G, is lined with compressed aluminium nitride. The electric resistance furnace, F, is detachable. The electric resistance consists of compressed carbon discs. These are arranged in eight columns each 1.2 metres

FIG. 16.



Diagrammatic representation of Serpek apparatus.

long, which cross the furnace diametrically and which are connected in series. The resistances are fed by a direct current of 10,000 amperes at 230 volts. Producer gas (about 30 per cent. CO + 70 per cent. N_2), which is formed in the generator, K, enters the lower end of G at a temperature of about 400° C. It passes through the kiln in the direction contrary to that of the descending charge, and in the electrically heated region, F, the nitrogen reacts with the alumina-carbon mixture in accordance with the equation (21). The producer gas, now enriched by the very hot carbon monoxide formed by the reaction, issues from the upper end of the kiln into the vertical chamber, B, preheating the descending charge as it moves along. At *a*, *b*, *c* and *d*, it meets with a blast of air which causes the carbon monoxide to burn to carbon dioxide, and the heat produced is employed to calcine and preheat

the bauxite in the upper kiln. The nitride formed in the electrically heated region, F, is collected in the airtight chamber, H. It contains about 26 per cent. of nitrogen.

FORMATION OF AMMONIA FROM ALUMINIUM NITRIDE.

When aluminium nitride is treated with dilute aqueous alkali, ammonia is produced, the reaction being expressed by the equation:

$$(22)\quad AlN + 3H_2O = Al(OH)_3 + NH_3.$$

The decomposition takes place readily when the nitride is heated with the dilute alkali in an autoclave, with constant agitation, for from two to two and one-half hours under a pressure of two atmospheres, the ammonia being drawn off from time to time. The molecular ratio of sodium hydroxide to aluminium nitride is 1 : 1.5.

In addition to ammonia, a very pure alumina (free from silica and iron) is obtained even from the decomposition of an exceedingly impure nitride made from a low-grade bauxite. While this alumina is not particularly suitable to use over again for the production of more nitride, as owing to the absence of impurities it would require a much higher temperature than is required with bauxite, it is very suitable for the production of metallic aluminium.

ENERGY REQUIREMENTS AND YIELDS.

In the Serpek process there are required, in addition to the heat from coal and producer gas, about 12 kilowatt hours of electrical energy for each kilogram of nitrogen fixed. With a consumption of one kilowatt year, 500 kilograms of nitrogen may be fixed and two tons of by-product alumina produced.

V. ABSORPTION OF NITROGEN AS CYANIDES.

Although it has long been known that cyanide can be formed by heating a mixture of carbon and alkali carbonate in an atmosphere of nitrogen, the development of this reaction for the fixation of atmospheric nitrogen on a commercial scale is due to the work of Bucher, carried out in the United States since the beginning of the war. Although the Bucher process is now working successfully in several small installations, the mechanical difficulties of production on a large scale have still to be solved.

In this process a mixture of soda ash and ground coke, or

carbon in any form, is heated in contact with finely divided iron in small retorts to a temperature of from 900° to 950° C. Nitrogen or air is passed through the heated mass, the nitrogen slowly reacting to form sodium cyanide, in accordance with the equation:

$$(23)\quad Na_2CO_3 + 4C + N_2 = 2NaCN + 3CO_2 - 138{,}500 \text{ cal.}$$

The part played by the iron in the reaction is that of a catalyst. The sodium cyanide may either be obtained by distillation of the reaction product, or by lixiviation with hot water.

The sodium cyanide formed in the reaction can be converted readily with air and steam into ammonia as follows: The cyanide is maintained just above its melting point and a current of air passed through the molten mass. It burns to sodium cyanate according to the approximate equation:

$$(24)\quad NaCN + \text{air} = NaCNO + 2N.$$

The nitrogen thus formed may be conducted into the cyanide furnaces. The sodium cyanate is then heated with water, which converts it into ammonia long before the boiling point is reached, in accordance with the equation:

$$(25)\quad NaCNO + H_2O = NaHCO_3 + NH_3.$$

The sodium bicarbonate may be used over again in the production of more cyanide.

Unlike other processes for the fixation of atmospheric nitrogen, in this cyanizing process no power factor of any considerable magnitude is involved. Of the raw materials the iron is always recoverable. This also applies to the sodium carbonate, if the final product is ammonia. The raw materials actually expended are, therefore, coke and nitrogen for the cyanizing reaction, steam for the production of ammonia, and coal for furnishing the heat. Bucher has suggested the possibility of employing for fuel the three moles of carbon monoxide formed in the reaction expressed by equation (23), which when burned would yield:

$$(26)\quad 3CO + O_2 = 3CO_2 + 200{,}000 \text{ cal.}$$

The process at the present time involves a large investment and high labor and repair charges, but, as previously mentioned, if the mechanical difficulties are successfully overcome, it appears that nitrogen may be fixed in the form of cyanide more cheaply than by any of the processes already described.

(To be concluded.)

ON THE DETERMINATION OF THE ELECTRICAL AND ACOUSTIC CHARACTERISTICS OF TELEPHONE RECEIVERS.*

BY

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I. INTRODUCTION.

SINCE its invention, in 1877, the telephone receiver as originally developed by Alexander Graham Bell has come into almost universal use.[1] In almost all methods of transmitting intelligence by electrical means, it constitutes the final link whereby electrical energy is converted into acoustic energy and thus made perceptible to the ear as sound. In recent years, with increasing ranges of transmission in telephony and radiotelegraphy, more attention has been directed to the telephone receiver itself as a vital part of the receiving apparatus in its essential function as a detector of extremely small variations of electrical energy. Regarding the telephone receiver as an electrically operated acoustic radiator, it will be evident from results discussed in the sequel that much remains to be done in the matter of its improvement. The writer therefore proposes to discuss briefly the main features of the instrument in its present form with a view to directing attention to points requiring further investigation. No attempt will be made to treat the subject exhaustively in the scope of the present article, as several treatises are now available to readers interested in matters of detail.[2]

II. ELEMENTARY THEORY OF THE TELEPHONE RECEIVER.

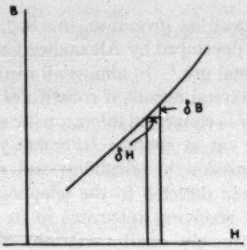
In its essential mode of operation, the telephone receiver remains practically the same as when it was first invented. In the bipolar receiver, a thin circular diaphragm of soft iron (japanned or tinned to prevent rusting, about 5.5 cm. in diameter and 0.02 to 0.05 cm. thick) is firmly clamped around its outer edge and usually has its free period of vibration or resonance frequency

* Communicated by the Author.

in the neighborhood of 1000 cycles. The diaphragm is subjected to the pull of a permanent magnet having its poles close to, but not actually touching it; as a result it is distorted to a slightly concave form, as indicated in Fig. 1. Surrounding the poles, and thus interlinked with the magnetic circuit, are wound two coils of silk-insulated or enamelled copper wire, each containing several hundred turns. A small electrical current δi through the coils will result in a variation of the magnetizing force $\delta H \propto \delta i$ acting on the magnetic circuit. If B denotes the average flux density

FIG. 1.

FIG. 2.



in the gap it will be connected with the magnetizing force H due to the permanent magnet by some such curve as that shown in Fig. 2. As H is altered slightly by the field δH set up by the current δi in the coil, it is seen that for small variations $\delta B \propto \delta H$, very approximately,* and hence $\delta B \propto \delta i$. If F denotes the total traction on the diaphragm due to the flux B, $F \propto B$,[2] and $\delta F \propto 2B\delta B$, giving, finally, $\delta F \propto 2B.\delta i$. Regarding the diaphragm as a static elastic system, the displacement $\delta x \propto \delta F$, from which it follows that $\delta x \propto 2B.\delta i$; in other words, under these conditions the to-and-fro motion of the diaphragm, giving rise to corresponding sound-waves, follows faithfully the variations of current represented by δi. It will be noticed that the one essential condition for this result is that there exist a constant permanent flux B in the gap as provided for by the permanent magnet.

The assumption involved in the statement $\delta x \propto \delta F$ is legitimate

* In reality the small variations of B and H trace out a minute hysteresis loop detrimental to the exact reproduction of current fluctuations.

for vibrations of frequencies not too close to resonance, but ignores the dynamics of the diaphragm. Regarding the diaphragm as a vibrating system of one degree of freedom, its motion will be characterized by a differential equation of the type

$$md^2x/dt^2+kdx/dt+\mu x=F \quad \ldots\ldots\ldots\ldots \quad (1)$$

where m is a mass-factor, k a factor representing dissipation of energy due to acoustic radiation, air-friction, eddy-currents, elastic and magnetic hysteresis, etc., and μ a stiffness constant depending on the elastic constants and dimensions of the diaphragm, method of mounting, etc. F represents the traction on the diaphragm resulting from the variation of telephonic current as already explained. A discussion of the consequences of equation (1) would carry us beyond the limits of the present article. It suffices to state that the motion of telephone receiver diaphragms has recently been studied in great detail by Kennelly and his pupils,[3, 4, 6] who describe experimental methods of determining the mechanical constants (m, k, μ) as well as the electrical constants involved in F of equation (1).

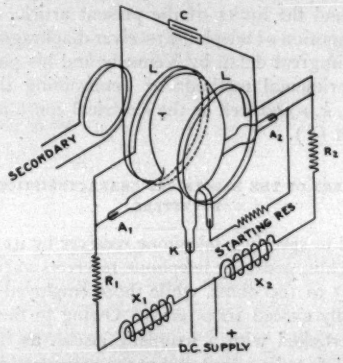
III. MEASUREMENT OF THE ELECTRICAL CHARACTERISTICS OF TELEPHONE RECEIVERS.

It is usual to specify a telephone receiver by its direct current resistance. Thus, ordinary telephone receivers vary in D.C. resistance from 25 to 100 ohms, while those employed in radiotelegraphy generally exceed 1000 ohms. Owing to the fact that the coils are interlinked with a magnetic circuit as in an ordinary transformer, it is to be expected that the resistance and inductance of the electrical circuit to an alternating current of pure wave-form will depend on the frequency. This dependence is further complicated by the motion of the diaphragm and by the eddy-currents generated in it by its motion in the field of the permanent magnet. Owing to the variable reluctance in the air-gap of the magnetic circuit, the electrical constants will depend on the magnitude of the measuring current, which should be specified directly, or stated in terms of the voltage across the terminals of the receiver.

The actual measurements of the electrical constants of a receiver over the range of telephonic frequencies (100 to 2500 cycles) was until recently a matter of some difficulty owing to the

practical impossibility of generating high-frequency alternating currents of pure sine wave form. This difficulty has now been eliminated by the introduction of the "Vreeland Oscillator," an indispensable adjunct to telephone research equipment as a generator of alternating currents of high frequency (300–2500 cycles) and pure wave-form.[5] The essential feature of the apparatus illustrated in Fig. 3 is a capacity-inductance circuit in which electrical oscillations are generated by a mercury-vapor arc deflected alternately between two electrodes from a third by the magnetic field of the coil forming the inductance. The oscillations thus set

FIG. 3.



Theoretical diagram of Vreeland oscillator.
(Reproduced with the kind permission of the Vreeland Apparatus Company, New York.)

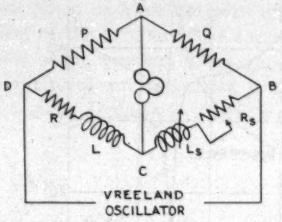
up are self-perpetuating and may have their frequency adjusted to any desired value by varying the capacity and inductance of the oscillating circuit. A potential between six and twenty volts (on a high-resistance circuit) is obtained across the terminals of a coil closely coupled with that of the oscillating circuit. The purity of the wave-form is stated to be extreme, the most rigid tests having failed to detect any harmonics.

Such a source of alternating E. M. F. is especially well adapted to the measurement of inductance and resistance of telephone receivers by the Rayleigh bridge. The arrangement shown in

Fig. 4 has been found to be most convenient for the purpose. P and Q are two non-inductive resistances, preferably adjusted to equality. The coil to be measured, having resistance R and inductance L, is inserted in the third arm of the bridge while (L_s, R_s) represent a variable resistance and inductance inserted in the fourth arm. This is best provided for by a non-inductive resistance box connected in series with some form of continuously adjustable inductance such as the Ayrton-Perry Inductometer.

The alternating potential is applied across BD, while a sensitive receiver is connected across AC. The inductance is first adjusted until minimum current passes through the telephone and the resistance then varied until the current is still further reduced.

FIG. 4.



Finally, after a series of successive settings of L_s and R_s, a very close approach to dead silence may be obtained in the telephone. As zero current in this part of the network implies equality of voltage and synchronism of phase at A and C, the condition for a balance is

$$R/R_s = L/L_s = P/Q \quad \ldots\ldots\ldots\ldots\ldots (2)$$

The electrical characteristics of telephone receivers as measured in this way have been studied in great detail by Kennelly and his co-workers.[6] The results of a series of observations carried out in this way on a Bell bipolar receiver of 87 ohms D. C. resistance are shown graphically in Fig. 5. If I be the r. m. s. value of the alternating current and R the effective resistanc at a given frequency, the electrical input is I^2R watts. If R_0 be the direct-current resistance, the corresponding copper loss is I^2R_0 watts. It may be mentioned in passing that the extent to which the A. C. resistance differs from the D. C. resistance is a measure of

internal energy losses and often serves as a rough indication of the relative merits of different types of telephone receivers.

IV. NOTE ON THE PRECISION MEASUREMENT OF FREQUENCY.

In telephonic researches the exact measurement of frequency is of great importance, especially in studying the characteristics near resonance. A very satisfactory precision sonometer was

FIG. 5.

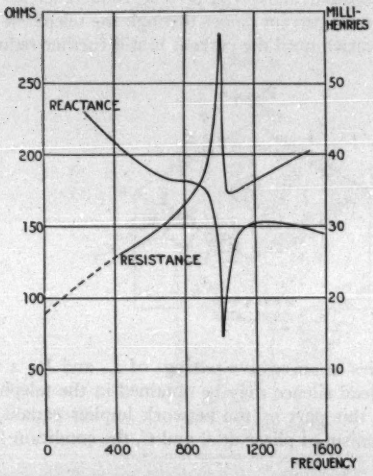
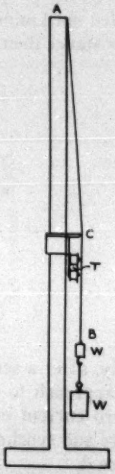


FIG. 6.



devised by the writer for the purpose and is shown diagramatically in Fig. 6. One extremity of a fine steel wire (1.373 grammes per metre) about a metre long was fastened at *A*, the upper end of a vertical cathetometer scale. The reading telescope was removed from the sliding support and replaced by a sharp bevel edge *C* about 4 cm. wide, constructed of brass. The same support carried a telephone magnet *T* mounted in such a way as to allow of vertical and horizontal adjustment. The lower extremity *B* of the wire was firmly soldered into a short perforated copper plug (2 mm. diameter × 5 mm.) which could be screwed into the centre

of the upper end of a cylindrical weight w (188.2 grammes) carrying a hook in the centre of its lower end as shown in the figure. To this hook could be attached a series of weights W (in practice a kilogramme weight was used). The coils of the telephone magnet were connected through suitable resistances across the alternating e. m. f., and the movable bevel-edge adjusted up and down until the wire BC was set into vibration. The inertia of the mass w was so great that the lower end B of the wire could be considered fixed for vibrations over the range of telephonic frequencies. The length could be accurately read off on the cathetometer scale by means of the vernier, the zero having been determined by bringing the bevel edge into coincidence with B, the upper surface of the copper plug into which the wire was inserted. Care was taken to leave the wire under full tension in the determination of the zero to allow for elastic stretching which was noticeable, as the wire was stressed to a degree not far from the elastic limit to obtain as great a length l as possible corresponding to a given frequency, given by the well-known formula

$$f=\frac{1}{2l}\sqrt{\frac{T}{m}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where T is the tension in dynes and m the mass of the wire per unit length. As long as the vibrating portion remained less than 50 cm. in length, it was easily shown by calculation that variations in that of the upper inclined portion of the wire did not affect the value as read off on the cathetometer scale to one part in a thousand.

Owing to this particular method of mounting the vibrating wire the length and tension were extremely determinate while dissipative forces were reduced to a minimum, with the result that the resonance was correspondingly sharp. It was found that the maximum resonance could be visibly altered by a variation of 1/10 mm. in a length of 30 cm. or by an alteration of 2 grammes in a tension of 1 kilogramme. In the course of the writer's researches the instrument just described was found to be extremely convenient in frequency determinations over a range varying from 360 to 1600, with an accuracy represented by an error less than one part in a thousand.

V. MEASUREMENT OF THE AUDIBILITY CHARACTERISTICS OF TELEPHONE RECEIVERS.

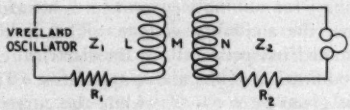
Determination of Audibility Current and Voltage.—In many applications it is important to know the sensitiveness of a telephone receiver. This may be defined as the minimum electric energy required to give an audible sound. The current required to give a just audible sound is referred to as the *audibility current*, while the voltage across the terminals is similarly referred to as the *audibility voltage*. It is to be expected that these characteristics will depend on several factors other than the design of the receiver, such as the sensitiveness of hearing of the observer, type of signal under consideration, existence and nature of extraneous sounds, etc. As far as possible a telephone receiver should be tested by an observer under the same conditions as those in which he will use the instrument in practice. As a receiver must in the last analysis serve to detect electrical currents by its effect on the ear, it is evident that an audibility test is the final measure of the effectiveness of the instrument for this purpose.

Several methods of testing telephone receivers have been described by various writers.[7, 8, 9] For details of the experimental arrangements, the reader is referred to the original papers. One of the methods most commonly used involves shunting the receiver by a non-inductive resistance until the telephonic current is so far reduced that the sound is rendered just audible. It is assumed that the current through the receiver may be calculated by the usual formulæ for inductive currents, the effective resistance and inductance having been determined by some such method as that described above. In view of the high frequencies involved, special precautions must be employed in ascertaining that all the resistance-boxes are of negligible inductance. According to Lord Rayleigh,[7] resistance boxes of more than 10,000 ohms should not be employed, owing to the capacity effect of the insulation. Even if these conditions are satisfied, a further element of uncertainty exists, owing to the fact that the effective resistance and self-induction of the receiver are measured for currents of a few milliamperes and may differ considerably from the values corresponding to the audibility current—a possibility first pointed out by Austin.[9] Further difficulties are met with in eliminating the direct inductive effect of the alternating current in the various circuits on the coils and diaphragm of the receiver itself, a source

of trouble which is all the more difficult to eliminate as the receiver is more sensitive.

A simple method of determining the audibility characteristics of receivers was devised by the writer in the course of telephonic researches, in which the above-mentioned difficulties are almost entirely eliminated. The circuit is shown diagrammatically in Fig. 7. A primary circuit of self-induction L, resistance R_1, and impedance Z_1, is connected across the terminals of the Vreeland oscillator, whose voltage V is measured by an electrostatic voltmeter. The telephone receiver is connected to form part of a

FIG. 7.



secondary circuit of self-induction N, resistance R_2, and impedance Z_2, loosely coupled with the primary, so that M is small compared to L or N.

Audibility Voltage.—The telephone receiver is connected directly across the secondary, whose resistance and self-induction are both made small compared to that of the receiver itself. A non-inductive resistance R_1 of the order of a megohm * is inserted in the primary circuit, so that $Z_1 = R_1$ very approximately. If x be the current in the primary, the voltage across the terminals of the receiver is $e = 2\pi f.M.x$ very approximately, while $x = V/Z_1 = V/R_1$ very nearly. Hence we obtain

$$e = 2\pi f M V/R_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

In practice it is convenient to vary the mutual inductance until the sound in the receiver is just audible, when the audibility voltage may be obtained from (4) independently of the electrical characteristics of the receiver, if M is known experimentally or determined by calculation. In the writer's researches two coaxial coils were used, the primary of 341 turns having a resistance of 1.28 ohms, self-induction .0317 henry and mean radius 10.7 cm. The secondary consisted of a small coil (300 turns, 17.4 ohms resistance, .013 henry self-induction, 3.9 cm. mean radius) arranged to slide along a central rod so that the mutual induc-

* The resistance of a graphite pencil-mark along a groove cut into an ebonite slab is suitable for the purpose, as having negligible self-induction and capacity.

tion with respect to the primary varied from 2.6×10^{-3} henry to 0.1×10^{-3} henry at 35 cm. distance between the coils. From a calibration curve, M could easily be read off in terms of the distance between the coils. To avoid direct inductive effects, it was found necessary to set up the testing apparatus at a considerable distance from the Vreeland oscillator (about 25 feet) and to bring the current to the primary through a twin wire cable enclosed in a grounded lead sheath.

Audibility Current.—In view of the fact already mentioned that the effective impedance of a telephone receiver depends on the value of the measuring current and is uncertain (and probably not determinable) for audibility currents, it is unsafe to determine the latter from the audibility voltage. The audibility current may be determined independently of the electrical characteristics by a slight modification of the above apparatus. The current in the primary is given by $x = V/Z_1$, while the current in the secondary is given by $i = 2\pi f M x / Z_2$. A high non-inductive resistance R_2 of the order of a megohm * is inserted in the secondary, so that $Z_2 = R_2$ very approximately, and in these circumstances

$$i = \frac{2\pi f M}{R_2} \frac{V}{Z_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

a relation in which the impedance of the telephone receiver does not enter as long as it remains of the order of a few thousand ohms. As before, M is altered until the limit of audibility is reached. In this case it may be necessary to make x fairly large to get an appreciable current in the high-resistance secondary. To avoid the direct inductive action on the receiver it is advisable to connect it through grounded metal-sheathed cable and determine audibility at a considerable distance from the primary coil.

The electrical and audibility characteristics of a typical wireless telephone receiver tested by the writer is given as follows:

D. C. resistance of two receivers of head-piece in series 2900 ohms.

At 1020 cycles:

Effective resistance ..... 4970 ohms } measuring current
Effective inductance ..... 0.890 henry } 0.79×10^{-3} amperes.
Audibility voltage ..... 9.0×10^{-6} volts

At 500 cycles:

Effective resistance ..... 4210 ohms } measuring current
Effective inductance ..... 1.140 henry } 0.95×10^{-3} amperes.
Audibility voltage ..... 38.0×10^{-6} volts

* The resistance of a graphite pencil-mark along a groove cut into an ebonite slab is suitable for the purpose, as having negligible self-induction and capacity.

VI. ON THE ACOUSTIC OUTPUT AND EFFICIENCY OF TELEPHONE RECEIVERS.

Although it was pointed out many years ago by Abraham [10] that the acoustic efficiency of the usual type of telephone receivers was *at most* 1/700, little success seems to have been made in remedying the poor acoustic performance of these instruments. The ability of the telephone receiver to detect very small variations of electrical energy is due more to the extreme sensitiveness of the ear as an organ of perception than to any inherent excellence of mechanical or electrical construction.

The amplitude of motion of a telephone diaphragm for an easily audible sound is of the order 10^{-3} to 10^{-4} centimetre. The detailed study of diaphragm vibrations recently carried out by Kennelly and his collaborators has furnished the writer of this article with material for calculating the acoustic output and efficiency of the corresponding telephone receivers. In a theoretical investigation by the writer, which it is hoped to publish shortly, the acoustic radiation from a vibrating diaphragm is calculated on the basis of Lord Rayleigh's theory.[11] The diaphragm is supposed to vibrate so that every part of its surface is oscillating in the same phase, an assumption which is legitimate as long as no natural overtones are excited. If W is the amplitude of motion of any point of the diaphragm, the *volume-displacement* is defined by

$$V = \int W dS \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

V represents the volume included between the equilibrium and extreme positions of the diaphragm. Provided the wave-length is large compared to the dimensions of the diaphragm, the energy radiated per second in a large open space is given by

$$[dw/dt] = \frac{1}{8} \frac{\rho_0 n^4 V^2}{\pi c} \quad \ldots\ldots\ldots\ldots \quad (7)$$

where ρ_0 is the density of the medium, f is the frequency, $n = 2\pi f$, while c is the velocity of sound in the medium.

In a paper by Kennelly and Taylor,[4] explorations over the surface of a vibrating telephone receiver were carried out and the corresponding current was measured. For the details of the measurements reference must be made to the original paper. In particular a curve is given from which the mean amplitude at

various radial distances may be obtained in the case of a bi-pole, 87 ohm, Bell telephone receiver vibrating without the cap over the diaphragm. The vibration contours were obtained at resonance frequency, $f = 992$ cycles, and show marked lack of symmetry owing to the magnetic tractions being applied over the two poles. A rough calculation by quadratures gave for the volume-displacement $V = 3.8 \times 10^{-3}$ cm.^{3} Writing $\rho_0 = .00129$ and $c = 3.3 \times 10^4$ cm./sec. for air at ordinary temperature and pressure, we obtain

$$[dw/dt] = 34.2 \text{ ergs/sec} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Unfortunately the effective resistance of the receiver in question was not given, but the value at resonance for one of practically identical construction is quoted as $R' = 225$ ohms. The current $I = .00202$ amperes. Hence

$$(\textit{electrical input}) = I^2R' = 9120 \times 10^{-7} \text{ watts} = 9120 \text{ ergs/sec} \quad \ldots\ldots \quad (9)$$

Comparing (8) and (9) we obtain for a rough estimate of the acoustic efficiency *at resonance* the ratio

$$\eta = .00375 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

It is to be expected that the acoustic efficiencies at frequencies far removed from resonance will be very much less than the above value. In Table I of a paper by Kennelly and Affel [3] are given the effective resistances R' and maximum displacements $|x|$ at the centre of a receiver diaphragm (with cap in position) for various frequencies between 429 and 1137 cycles at constant current $I = .00204$ ampere. As the volume-displacements are proportional to $|x|$ (assuming geometrically similar vibration contours over the frequency range) and the electrical power-input at constant current is proportional to the effective resistance R', it follows from (7) and (9) that the ratio of the efficiency at a given frequency to that at resonance is given by the expression

$$\frac{\eta}{\eta_r} = \frac{f^4 |x|^2 R'_r}{f_r^4 |x_r|^2 R'} \quad \ldots\ldots\ldots\ldots\ldots \quad (11)$$

where the suffix r refers to resonance conditions. Quoting a few values from Table I of the paper by Kennelly and Affel,[4] we derive the following:

TABLE I.

Frequency cycles/sec.	R' ohms	$\lvert x \rvert$ cm.	$\frac{\eta}{\eta_r}$	Remarks
429	130	1.8×10^{-4}	.0016	
70	153	1.6	.0075	
804	166	1.9	.0175	Current I = .00204 r. m. s. amperes throughout.
923	193	2.85	.0580	
987	254	6.03	.256	
1020.4	224	10.45	1.000	Resonance frequency 1020.4.
1043	151	7.60	.857	
1137	159	0.95	.018	

Keeping in mind that the resonance efficiency as already deduced is in the neighborhood of 4/1000, it will be deduced from the above table that the efficiency over the ordinary range of frequencies is extremely low, amounting to only a few parts in a hundred thousand or a million.

It is thus evident that the telephone receiver, considered as a means for transforming electrical energy into acoustic output, is an extremely inefficient instrument. It remains for future research to determine the location of the energy-losses and to remove their cause if possible. According to some experiments by the writer, it appears that magnetic hysteresis losses are chiefly contributory. The depth of penetration of flux variations into the permanent magnet due to high frequency telephonic currents in the coils is very small, amounting perhaps to a tenth or hundredth of a millimetre. Unfortunately it is this flux variation which is effective in causing the diaphragm to vibrate, and only a moderate degree of improvement can be obtained by reducing eddy-currents by lamination. The losses just referred to may be reduced to some extent by welding to the permanent magnet spool cores of low-hysteresis iron (such as silicon steel or vacuum-distilled iron). Unavoidable hysteresis and eddy-current losses are, however, set up by the vibration of the diaphragm in the strong magnetic field due to the permanent magnets.

In a recent paper by Kennelly and Nukiyama,[12] it is estimated that in the particular telephone receiver whose constants are quoted in Table I above, forty per cent. of the electrical input is delivered at resonance to the diaphragm as mechanical output, including internal frictions and acoustic delivery. The estimate of acoustic efficiency at resonance calculated in the present paper (0.375 per cent.) shows that only about one per cent. of the

mechanical power delivered to the diaphragm is converted into sound, the remainder being dissipated as heat by the action of elastic hysteresis, internal air-friction and eddy-motion, frictional losses at the clamped boundary, etc. The problem of designing diaphragms to reduce these losses to a minimum constitutes in the writer's opinion a most important field of research connected with improvements in the acoustic efficiencies of telephone receivers.

For the intelligible transmission of speech the telephone receiver must respond without too great variation in loudness to a wide range of frequencies; or, in other words, resonance must not be too sharp. This requires a high degree of damping, involving large energy-losses and inevitable low efficiency.

The case is otherwise when it is required to detect small alternating currents. As far as possible dissipative forces should be reduced to a minimum and the receiver should be designed to operate at the resonance frequency of the diaphragm. The less the energy-losses and the greater the sensitiveness of the instrument and the sharper is the resonance of the diaphragm.

The recent trend of radiotelegraphy in the matter of power economy and long distance transmission has led to a demand for increased sensitiveness in the receiving apparatus. This has been met by the introduction of current amplifiers of various types, giving magnification amounting in some instances to a hundredfold or more. The telephone receiver is, however, an essential part of the receiving apparatus and any marked improvements in its construction leading to higher acoustic efficiencies are greatly to be desired. In the reception of radio-telegraphic signals involving the detection of periodic fluctuations of current considerable gain in sensitiveness may be obtained by employing a receiver whose diaphragm is tuned to resonance with the frequency of the telephonic current. In a sensitive receiver in which energy-losses are reduced to a minimum, the resonance will be fairly sharp. In order to meet unavoidable variations of spark frequency occurring in practice, a receiver having a diaphragm capable of continuous tuning over a considerable range of frequencies would enable it to be always employed at maximum sensitiveness, an advantage which will be realized from an inspection of Table I, in which a change of frequency from resonance at 1020 to 987

cycles is shown to result in the reduction of efficiency to one-fourth of the maximum value.

It is hoped that the present article will serve to direct attention to the need for further research directed towards the improvement, in regard to acoustic efficiency, of existing forms of telephone receivers, in view of their almost universal use in radio-telegraphy and other forms of signalling across space.

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[12] KENNELLY, A. E., and NUKIYAMA, H.: "Electromagnetic Theory of the Telephone Receiver," *Proc. American Institute of Electrical Engineers*, Vol. xxxviii, April, 1919, pp. 491–539. Extensive references are made in this paper to the most recent researches on telephone receivers.

Production of Smoke Screens in Warfare. G. A. RICHTER. (*Proceedings of the American Electrochemical Society,* April 3–5, 1919.)—When smokes were first demanded by the fighting forces of the Army and Navy, the ordnance deparments furnished quantities of phosphorous for that purpose. It was soon realized that other more avialable smoke mixtures must be developed to meet the demands. Early work had indicated that hydrochloric acid gas when reacting with ammonia vapors could under certain conditions produce a smoke having satisfactory obscuring power. The difficulty of handling large quantities of hydrochloric acid as such made it necessary to employ other means.

Advantage is taken of the property of both the silicon and titanium tetrachlorides to hydrolyze readily, forming hydrochloric acid and a residum of the corresponding oxide or hydroxide. The speed of such hydrolysis can be controlled. It is a well-known fact that a quantity of the titanium chloride left exposed to the action of moist air will fume for several hours, the time depending on the surface exposed and the humidity of the atmosphere. If the same amount of the tetrachloride is suddenly dispersed by means of an explosive charge, there results a much larger cloud for a correspondingly shorter period. The same is true of silicon tetrachloride, although the cloud produced is of less intensity. In the presence of ammonia, the clouds obtained with both the tetrachlorides are intensified even more, due to the formation of ammonium chloride.

In order to obtain the greatest total obscuring power, the following conditions are necessary: (1) The liquid ammonia and the silicon tetrachloride must be sprayed into the atmosphere in a finely atomized state. (2) The smoke apparatus must allow a great dilution of both ingredients with air before they are allowed to mix. (3) There should be sufficient moisture in the air to allow a complete hydrolysis of the silicon tetrachloride before the vapors come in contact with the ammonia vapors. The Navy Smoke Funnel and the smoke knapsack, devised for trench warfare, are both designed to conform to these conditions. The ammonium-titanium tetrachloride under laboratory conditions gives better results than the silicon compound, but its slowness of evaporation causes gumming of the nozzels. It was never used in the smoke funnel manufactured for the American Navy.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE VISCOSITY OF GASOLINE.[1]

[ABSTRACT.]

THE short tube viscosimeters which are in ordinary use for determining the viscosity of lubricating oils cannot be used with gasoline, for which it is necessary to employ an instrument with a much longer outlet tube. The Ubbelohde viscosimeter, primarily designed for kerosenes, appeared suited to the purpose and two instruments of this type were used in determining the relation between time of discharge and viscosity in poises. By a large number of runs with water and ethyl alcohol solutions, liquids of known viscosity, it was found that:

$$\text{Kinematic viscosity} = \frac{\text{viscosity in poises}}{\text{density, } g \text{ per cc}} = .0000887\, t - \frac{1.438}{T}$$

where t is the time of discharge in seconds. The published standard dimensions of the instrument give .125 centimetre as the inside diameter of the outlet tube, but this was found to be .129 in the instruments tested. The time of discharge for 100 cubic centimetres of water at 20° C. (68° F.) was found to be very close to the specified value of 200 seconds. It is therefore suggested that 200 seconds should be retained as standard, but that the diameter of the outlet tube should be changed to .129 centimetre.

In dealing with highly fluid liquids such as gasoline, it is convenient to use the fluidity or reciprocal of the viscosity in poises in place of the viscosity. The temperature-fluidity curve is very much more nearly a straight line than is the temperature-viscosity curve. Fluidities were found for thirteen samples of gasoline and one kerosene over a temperature range from 5° to 55° C. (41° to 131° F.). These tests showed that kerosenes have a lower fluidity or higher viscosity than water, while gasolines, though varying greatly among themselves, are all more fluid than water. This is in agreement with the published data in regard to kerosene; the available information in regard to the viscosity of gasolines is very meagre.

It is generally recognized that the gravity test is an uncertain

* Communicated by the Director.

[1] Technologic Papers, No. 125.

guide to the quality of kerosene or gasoline, if taken by itself without information as to the source of crude oil. This was confirmed by the tests on gasolines, their order when arranged according to densities being quite different than when arranged according to fluidities. A fractional distillation is often used as a substitute or supplement to the gravity test, and this gives valuable information. It requires, however, more complicated apparatus and greater skill than needed to test fluidity. Furthermore, the close relation between fluidity and vapor pressure, which has been pointed out by Bingham [2] points to the conclusion that fluidity may be an extremely good criterion for volatility.

Bingham gives tables of fluidities of various pure chemical compounds over a wide range of temperatures, and these tables were used to compare the fluidities of the thirteen gasolines with those of the aliphatic hydrocarbons. It was found that ordinary commercial gasoline, as now sold for use in automobiles, has a fluidity slightly less than octane. Most of the special gasolines, intended for use in airplane motors, have a fluidity between that of heptane and hexane. The temperature-fluidity curves of these gasolines were nearly straight and parallel, so that the order of the different gasolines, arranged according to fluidity, would be nearly independent of the temperature considered. It is suggested that the specification of the fluidity at two temperatures might serve to define a desired grade of gasoline.

THE CONSTITUTION AND MICROSTRUCTURE OF SILICA BRICK AND CHANGES INVOLVED THROUGH REPEATED BURNINGS AT HIGH TEMPERATURES.[3]

By H. Insley.

[ABSTRACT.]

WITH the coöperation of many of the principal American manufacturers of silica brick, petrographic microscopic studies were made of the raw quartzite, the finished brick, and brick which had received repeated burns by actual use in kilns, coke ovens, etc., for the purpose of determining the original constitution, and also components of silica brick stable under conditions of

[2] E. C. Bingham, *Am. Chem. Jour.*, Vol. 43, p. 296, 1910.

[3] Technologic Papers, No. 124.

repeated burning such as it would undergo in the industries. Test cubes were also prepared in the laboratory of the Bureau of Standards according to a standard commercial mix and burned at 50° intervals from 1200°–1500° C. in order to trace out the mineralogical and structural changes with increasing temperature.

Quartz, cristobalite, tridymite, pseudo-wollastonite ($\propto$ –CaO.-SiO_2), and glass are found to be present in silica brick. Pseudo-wollastonite and glass are never present in anything but small amounts. The proportions of the other constituents vary according to the heat treatment undergone.

Microscopical quantitative analyses of the relative proportions of the three predominant minerals were made of each brick examined. These analyses show that the longer a brick is burned at high temperatures but below 1470° C., the greater will be the amount of tridymite present.

Silica brick are usually found to have a porphyritic-like structure made up of phonocrysts and groundmass. This structure is not due to any chemical or physical action which takes place during the heating or cooling of the brick but is caused by the method of grinding the raw material, the phonocrysts being the coarsely ground pieces while the groundmass is made up of finely ground material and rock flour.

Microscopic examination shows that the first inversion is from quartz to cristobalite and begins in the groundmass. The material which is broken up in the phonocrysts by shattering due to expansion on heating is then transformed into cristobalite and rims of cristobalite form around the phonocrysts similar in appearance to the reaction rims seen around minerals in natural rocks. After longer heating tridymite begins to appear in the groundmass. The crystals are at first very small and rather poorly developed but increase in size with successive reburnings. Tridymite is usually present as wedge-shaped and more complicated interpenetration twins. In reburned brick the quartz phonocrysts are occasionally entirely transformed to cristobalite and sometimes even tridymite crystallites begin to appear in the phonocrysts.

The lime added in the grinding of the raw materials does not appear to aid in the bonding of the brick by the compounds which it forms but rather by hastening the inversion of the silica through its fluxing action. Most of the bonding action seems to be due to the interlocking of the cristobalite and tridymite crystals. Any glass present aids but little in the bonding.

Permanent expansion is caused by the inversion of quartz to cristobalite and tridymite. A large proportion of tridymite is desirable in silica brick since it has the larger permanent expansion and subsequent buckling of the furnace walls is reduced to a minimum.

The investigation has verified the prediction of Fenner: that with a comparatively small amount of flux quartz inverts to cristchalite, then to tridymite at temperatures where cristobalite is the unstable and tridymite is the stable modification. In the case of every brick examined cristobalite was the first inversion product to form whether the conditions had been such as to promote much or little inversion. Moreover, the final inversion product reached after many reburnings to the temperature range where it was the stable modification, resulted invariably in the formation of tridymite.

THE ULTRA-VIOLET AND VISIBLE TRANSMISSION OF EYE-PROTECTIVE GLASSES.[1]

By K. S. Gibson and H. J. McNicholas.

MANY glasses are on the market and extensively advertised to protect the eyes from injurious radiant energy. Unfortunately, but little authoritative information concerning the properties of these glasses has been available. The public and even oculists and physicians have had little to guide them in selecting such glasses except the claims of makers and agents. One purpose of such glasses is to absorb the injurious radiant energy which is emitted along with the light from certain lamps as well as from welding arcs and industrial furnaces, while transmitting sufficient light for vision. They thus act as filters. Another purpose in certain cases may be to absorb part of the light so as to reduce a blinding brilliance. Glasses of different types are required for different needs. The degree to which these glasses actually fulfill their avowed purpose can only be determined by measurements of their "transmission" (*i.e.*, the ratio of transmitted energy to the energy falling on them) for the various forms of radiant energy in question. The Bureau of Standards has made such measurements on a great number of glasses now on the American market and the results are published in this paper.

[1] Technologic Papers, No. 119.

PHYSICAL AND CHEMICAL TESTS ON THE COMMERCIAL MARBLES OF THE UNITED STATES.[a]

By D. W. Kessler.

[ABSTRACT.]

THIS paper is the first report of the Bureau of Standards in connection with an extensive coöperative program for investigating the building stones of the United States. The other government departments participating in the work on different phases of this investigation are the U. S. Geological Survey, Bureau of Mines and Office of Public Roads.

This paper comprises the results of strength tests, water absorption, porosity, specific gravity, freezing, thermal expansion, electrical conductivity and chemical tests on fifty-two different types of marbles produced in this country. The purpose of the work is to determine the relative value of the different types for building purposes, and other special uses.

Compressive strength tests were made on specimens in the original condition and on specimens after being soaked in water for two weeks. The strength of the dry specimens gave values ranging from 7850 to 50,205 pounds per square inch. As a rule the soaked specimens gave lower compressive strengths than the dry, and in a few cases the loss due to soaking was over 25 per cent.

Transverse and tensile strength tests are included and show the strength of the specimens when broken perpendicular and parallel to the bedding planes.

The freezing tests made for this report consisted in determining the loss in weight and strength due to thirty freezings and thawings. While these losses were considerable in most cases, some samples showed practically no loss and occasionally a gain in strength was indicated. Hence it was decided that thirty freezings are not enough to give a trustworthy indication of the durability of such materials. An apparatus has been installed which automatically shifts the specimens back and forth between a cold chamber and warm chamber at certain intervals. With the use of this apparatus, it is possible to make a great number of freezings which will correspond to several years of exposure to the weather. It is proposed to make extensive weathering tests with this apparatus to determine more definitely the relative effect of

[a] Technologic Papers, No. 123.

frost action on the different marbles as well as other types of building stones.

Electrical resistivity tests were made on a number of different types to determine their relative value as insulators and resistivity under different conditions of moisture. The results show a considerable range of values, indicating that there is a choice of marble for use in switchboards and allied purposes.

Measurements of the thermal expansion made on a few samples of marble in this investigation show that this material does not expand at a uniform rate even at ordinary temperatures. As the temperature is increased the rate of expansion increases, hence it is not possible to state a coefficient of expansion for marble that will hold good for any very great range of temperatures. Another peculiarity brought out by these tests was the fact that marble when expanded by heating does not contract to its original dimensions as the temperature is lowered, but retains a part of the increase permanently. A number of successive heatings show the same effect, each adding an increment of length to the specimen.

A few cases of warped marble slabs are illustrated and a discussion is made of the causes which may be instrumental in bringing about this warping.

Casein Waterproof Glue. H. A. GARDNER. (*Aircraft Technical Note No. 46*, Navy Department, Bureau of Construction and Repair, May 23, 1918.)—The Forest Service has recently completed some very extensive tests with casein glue. These tests have demonstrated that there are now available, commercially at least, three brands which are all furnished by the makers in the form of dry compounds to be mixed with water. These glues are to be considered waterproof in the sense that they are not dissolved out or injured by water. Permanently prolonged soaking causes such glues to soften and become weak, but upon subsequent redrying they regain their former strength. The principal difficulty with these glues is in their rapidity of setting after being mixed with water; from two to five hours is the longest period of fluidity. Experimental batches of casein glue, to which certain materials have been added to delay the set, have, however, remained fluid and workable for periods as long as forty-eight hours.

Attempts have been made to determine what percentage of bad joints would occur in using casein glue. Every one of about 200 specimens made by ordinary mechanics was found satisfactory. It is believed that, if the instructions of the manufacturers are followed, casein glue is a safer material for aircraft construction than hide glue. It appears, therefore, for strength members in aeroplanes, that these glues should be used in place of hide glue.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

A NEW YELLOW DYE AND LIGHT—FILTERS MADE FROM IT.[1]

By C. E. K. Mees and H. T. Clarke.

[ABSTRACT.]

THE dyes previously used for making light filters were principally Picric acid, Tartrazine and Filter Yellow. Picric acid, while having a satisfactory absorption, is unstable and as a consequence the early gelatine filters were made chiefly with Tartrazine, which is quite stable. Tartrazine, however, has the disadvantage that it transmits the ultra-violet and that filters made from it are relatively inefficient.

The introduction of Filter Yellow in 1907 supplied a dye having a good absorption in the ultra-violet, reasonably sharp cut in the spectrum and great stability. It was still desirable for high efficiency, especially in filters for aerial photography, that a dye should be obtained possessing the stability and ultra-violet absorption of Filter Yellow but with greater sharpness of cut.

The compounds of phenyl hydrazine with sugars are yellow in color and a soluble compound of this type has been prepared by coupling glucose with parahydrazine-benzoic acid. The sodium salt of glucose-phenyl-osazone-para-carboxylic acid prepared in this way, proving to be a very suitable dye for the preparation of sharp cut light filters, has been given the name of "Eastman Yellow."

From this new dye light filters have been prepared under the designation of EK-1 and EK-2 filters, which are stable to light, have a very strong absorption for ultra-violet, and are considerably sharper and more efficient than K filters made from Filter Yellow.

* Communicated by the Director.

[1] Communication No. 75 from the Research Laboratory of the Eastman Kodak Company, published in *British Journ. Photog.*, 1919, p. 48, and *Journ. Ind. and Eng. Chem.*, current issue.

Concrete Freight Car. ANON. (*Communication from the Portland Cement Association,* March, 1919.)—New uses for concrete come frequently to public notice. One of the latest, and one that promises to be far-reaching, is the concrete freight car. The beginning of practical plans for the manufacture of reinforced concrete freight cars dates from 1909 when a patent for such a car was granted to Joseph B. Strauss, of Chicago. On account of the war, construction of a trial car was delayed, and it was but recently that the first car, of the gondola type, was completed by the R. F. Conway Co., Chicago, and tested under service conditions. Not only in the material used, but in its design and the details of construction, it represents an interesting departure from usual methods.

The basic feature of the design is a steel skeleton body forming the outer boundary of the car, and mounted upon a steel underframe. The concrete walls and floor are contained within this frame and, together with the frame and floor reinforcement, are connected to, and interlocked with, the underframe. The steel frame forms the finishing and protecting edges, thus entirely shielding the concrete and also serving as a complete system of stress-bearing members. In the construction of the test car, the "cement gun" was used. The forms were placed on the outside of the car, and the cement was shot against them from within. The outside of the car, that is, the surface against the forms, was given a smooth finish, but the interior was left much as it came from the gun.

Tests of the completed car, both empty and loaded, demonstrated its practicability for rough service. In the test without load it withstood extremely rough handling in switching, and came through without injury. Subsequently, the car was loaded with fifty-five tons (10 per cent. overload) of sand and turned over to a switching crew for service handling. It withstood this test also without injury. Other merits are claimed for the concrete car. It will not need painting and will practically eliminate maintenance charges. Its life will be much longer than that of the wooden car. It will have the important advantage, also, of being unaffected by its cargo, and will consequently be adapted better than the steel car for hauling slag and ashes.

Plans are already under way for the quantity manufacture of these cars. The fact that the first one was built with the sanction and coöperation of the United States Railroad Administration, and that the Illinois Central Railroad took an active interest in its construction and test, indicates that extensive production will not be long delayed.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE MECHANISM OF FRACTURE IN STEEL.

By W. E. Ruder.

[ABSTRACT.]

MICROSCOPIC examination shows that steel is crystalline in nature and heterogeneous in composition. Each constituent has its own physical and chemical characteristics, and the results which we get from the test bar are really summations of the physical characteristics of the constituents. Alternating stress is one of the most accurate methods for the determination of the true elastic limit.

The photograph illustrates very satisfactorily the difference in strength and the manner of fracture between large single crystals of the same steel which differ only in orientations. Crystals may have widely different strengths, which depend on the relation of the direction of orientation to the applied stress.

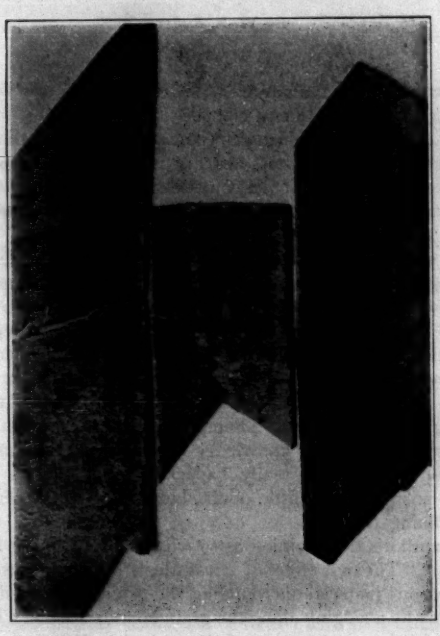
Howe's modification of Rosenhain's amorphous theory seems to offer the most plausible explanation of the greater strength of the grain boundaries. Thompson's surface tension theory adds very little to our knowledge and rather complicates our conception as to what really happens. That surface tension actually exists, there is little doubt, but it does not appear to be a determining factor.

The author's own opinion as to what happens in the fracture of steel is: "The first effect of stress, therefore, is to cause a flow of amorphous material surrounding the grains, indicated micrographically by a ridging along the grain boundaries and a molecular yield in the space-lattice of the crystals. When the elastic limit is reached the amorphous cement, as determined by the strength and amount of it, breaks transversely, owing to its weakness in that direction, and the load is suddenly thrown upon the crystal. The plastic yielding, due to slipping, causes a sudden drop in the applied stress, which, after sufficient intercrystalline amorphization takes place, again causes the applied stress to rise,

* Communicated by the Director.

but this time with considerable elongation. This is what the stress and strain diagram shows us actually happens. The unbroken part of the intercrystalline cement is not weakened and so still supports the crystal laterally."

The longer path of the intergranular cement, as compared



with internal shear, accounts for the fact that we do not have intergranular fracture in the case of suddenly applied loads. The strength of the grain boundaries, therefore, can be accounted for on the mere assumption that the amorphous boundary material is somewhat stronger than the crystalline phase without complicating our conceptions with further unnecessary assumptions.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN NUTRITION: I. THE NUTRITIVE VALUE OF COCONUT GLOBULIN AND COCONUT PRESS CAKE.[1]

By Carl O. Johns, A. J. Finks, and Mabel S. Paul.

[ABSTRACT.]

NUTRITION experiments with albino rats show that normal growth can be attained by animals fed a ration in which either coconut globulin or coconut press cake forms the sole source of protein in an otherwise complete diet. Enough water-soluble vitamine for normal growth is contained in coconut press cake, and the presence of an appreciable, though insufficient, quantity of fat-soluble vitamine is indicated. Preliminary experiments show that coconut press cake is deficient in inorganic constituents, probably calcium, phosphorus, and chlorine.

LYSINE AS A HYDROLYTIC PRODUCT OF HORDEIN.[2]

By Carl O. Johns and A. J. Finks.

[ABSTRACT.]

HERETOFORE lysine has never been reported to be present in hordein, the alcohol-soluble protein of barley. Using the Van Slyke method, the Protein Investigations Laboratory found that lysine constitutes 1.01 per cent. of hordein.

PREVENTION OF DUST EXPLOSIONS AND FIRES IN GRAIN THRASHING MACHINES.[3]

By David J. Price.

[ABSTRACT.]

NUMEROUS explosions and fires in thrashing machines have been reported throughout the large grain-growing sections of this

* Communicated by the Chief of the Bureau.

[1] Published in *Jour. Biol. Chem.*, v. 37, No. 4, April, 1919, p. 497.

[2] Published in *J. Biol. Chem.*, May, 1919.

[3] U. S. Department of Agriculture Bulletin 379.

country during the past few years. Since 1914 more than 700 have occurred in the Pacific Northwest alone, about 300 taking place in 1914 and almost as many in 1915. To determine the cause of these fires and explosions, and to develop methods of prevention, the U. S. Department of Agriculture has conducted an extensive investigation, during the course of which the following facts have been brought out:

Of the total number of machines thus affected in 1915 over 27 per cent. represented a complete loss, and 34 per cent. partial damage. the rest being but slightly affected.

More than 80 per cent. of the explosions and fires may be classified as wheat smut dust explosions, and approximately 76 per cent. originate near the cylinder in the front part of the machine. Over 75 per cent. of these occurrences were due to the ignition of the smut dust by the discharge of static electricity generated by the operation of the machine.

During the past three seasons three principal methods of prevention, developed and tested by the Department of Agriculture, have been generally adopted, and are now being made a permanent part of the machine equipment.

1. Installation of an effective fire extinguisher especially designed for thrashing machines. In the event of a fire, this not only saves the machine, but also prevents the spreading of flames to the nearby grain and straw.

2. The installation of an exhaust fan to collect and remove smut and dust from the separator, thus preventing the formation of an explosive mixture of dusts.

3. Installation of an effective grounding system for the removal of static electricity from the machine.

The field men of the Department have found that machines properly equipped in this way have not experienced explosions and fires, while those not so equipped have suffered extensive damage, with destruction also to the surrounding grain.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 16, 1919.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, April 16, 1919.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 8.

The following gentlemen were nominated by the Board of Managers for Honorary Membership:

Dr. John A. Brashear, Pittsburgh, Pennsylvania.

Prof. Heike Kamerlingh Onnes, Leiden University.

Dr. Thomas Alva Edison, Orange, New Jersey.

Prof. Theodore William Richards, Harvard University.

Col. John J. Carty, Chief Engineer, American Telephone and Telegraph Company.

Prof. Hendrik Antoon Lorentz, Leiden University.

Admiral David Watson Taylor, Chief Constructor, Bureau of Construction and Repair, United States Navy.

Senator Guglielmo Marconi, Rome, Italy.

Sir James Dewar, The Royal Institution, London, England.

Major General George Owen Squier, Chief Signal Officer, United States Army.

The nominations were duly seconded, and the gentlemen were unanimously elected.

The President advised the meeting that the Institute had become the residuary legatee under the will of the late Henry W. Bartol, and that to benefit by the will it was necessary for the meeting to adopt a resolution accepting the bequest. On motion, duly seconded, it was: *Resolved*, That the bequest and trust contained in the last will and testament and codicil of Henry W. Bartol be, and the same are hereby, accepted. The resolution was passed unanimously.

A report of progress was presented by the Committee on Library.

The President referred to the great loss the Institute had sustained through the death of its late Vice-President, Mr. Louis E. Levy, and recognized Mr. Coleman Sellers, Jr., who said:

> "In February last, the Institute lost by death one of its most useful and most devoted members, Mr. Louis E. Levy, Vice-President.
>
> "The Board of Managers at its meeting on February 19th, adopted an appropriate minute, and it seems fitting and desirable that the Institute itself should make a formal record of its loss and express in some measure its sense of appreciation of the character and services of such an exceptional man."

And then moved the adoption of the following minute:

"It is with a deep sense of its loss that The Franklin Institute of the State of Pennsylvania hereby records the sudden death on February 16, 1919, of its Vice-President, Louis E. Levy.

"Mr. Levy joined the Institute in 1881, was elected a member of the Board of Managers in 1903 and a Vice-President in 1916. In 1896 he was appointed a member of the Committee on Science and the Arts, for which he was peculiarly qualified by his broad scientific knowledge and inventive ability.

"The thirty-eight years of Mr. Levy's membership were years of willing, devoted and effective service to the Institute. There was probably no one of the Institute's activities in which he did not at some time participate. He was always prepared to do more than his share of any work required, and his genial character and kindliness endeared him to his associates.

"He was an unusual combination of desirable characteristics. For the breadth and depth of his knowledge and his ingenuity, he was remarkable. In his personality he was lovable. In character in all respects he was estimable. He was in truth a many-sided man, and all of his ability and attainments were freely given to his fellow man. He will long be mourned and missed by a wide circle of people of all sorts and conditions whom he served in some helpful manner. To The Franklin Institute he can hardly be replaced."

This motion was seconded by Prof. A. E. Outerbridge, Jr., who gave a brief account of Mr. Levy's scientific and technical achievements. The motion was unanimously carried.

The Chairman then introduced Hollis Godfrey, Sc.D., Eng.D., LL.D., D.C.L., F.R.G.S., President of Drexel Institute, Philadelphia, who presented the paper of the evening, entitled "Shipbuilding Analysis." The speaker outlined a very complete study he had made of the subject.

Lantern slides of diagrams and from original photographs taken at various shipyards were exhibited for the purpose of illustration. The progress of the work through various stages was also shown by means of charts, blue prints, card records, and other details. The speaker stated that the work as described made possible a material shortening of the time now taken for ship construction, and would also prove of importance in the education of shipyard workers.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

RESOLUTION ADOPTED BY THE BOARD OF MANAGERS ON THE OCCASION OF THE DEATH OF LOUIS EDWARD LEVY.

PHILADELPHIA, February 19, 1919.

The Board of Managers of The Franklin Institute learns with sorrow of the death of its esteemed fellow-member, Mr. Louis E. Levy, whose many activities in the work of the Institute have been of great value to it and to the public the Institute is organized to serve, and adopts the following Resolution to be published in the JOURNAL and a copy to be transmitted to his family:

RESOLVED, That through the death of Louis Edward Levy, The Franklin Institute has lost one of its most faithful and loyal friends.

Becoming a member of the Institute in October, 1881, he was, from the beginning of his membership, intensely interested in its different activities.

Appointed a member of its Committee on Science and the Arts in 1896, he served uninterruptedly either as member or chairman of that Committee. His genial personality, coupled with a clarity of insight, won for him a permanent place as a member of that Committee, and established between him and his associates a cordiality of relations that bound them to him as lifelong friends.

In 1916 he was elected to the Vice-Presidency of the Institute, a position which he filled with distinction.

During this term of thirty-eight years as member and official in this Institute, his services were given without stint to advancing its interests.

A man of high inventive skill, his discoveries in the field of the graphic arts have received distinguished recognition from the World's Fairs at Chicago, Paris, St. Louis and San Francisco, as well as the highest award in the gift of The Franklin Institute, the Elliott Cresson Gold Medal.

His work as editor, author and publisher is well known and appreciated in Philadelphia, while his articles in technical journals have been read with interest and profit. As Chairman of the Committee on Publications, his literary ability and experience enabled him to render efficient and valued service to the JOURNAL in both the literary content and technical excellence of which he was deeply interested.

He was a member of many technical societies, interested not only in those dealing with his own immediate interests, but also in those which treated of general scientific subjects, industrial improvements and social betterment.

A man of wide experience, he formulated a broad philosophy which was optimistic in its faith in the ultimate well-being of mankind.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 2, 1919.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, April 2, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following reports for reconsideration and final action were presented:

No. 2708: Waterbury Hydraulic Speed Gear. Potts Medal jointly to Reynold Janney, of New York, N. Y., and Harvey D. Williams, of Wallingford, Conn., adopted.

No. 2714: Snook's X-Ray System. Referred back to Committee for revision.

For first reading:

No. 2728: Landreth Electrolytic Sewage Process.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, March 6, 1919, at 8 o'clock, with Mr. G. H. Clamer in the chair. The minutes of the previous meeting were approved. The presiding officer introduced Robert Grimshaw, C.E., of New York City, a member of the Faculty of New York University, who delivered a lecture on "The Problem of Cost Reduction." The importance of the problem was shown; the factors (men, materials, markets, machines, and methods) and the subjects (labor, materials, and oncost) were described. Methods were enumerated for the solution of the problem by reducing cost of labor and material and oncost, and the results obtained were discussed. The paper was discussed. A vote of thanks was tendered Professor Grimshaw, and the meeting adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

Section of Physics and Chemistry.—A joint meeting of the section, and the Physics Club was held in the Hall of the Institute on Thursday evening, April 3, 1919, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

W. J. Humphreys, Ph.D., Professor of Meteorological Physics in the U. S. Weather Bureau, delivered a lecture on the "Optics of the Air." Perspective, refraction, diffraction, and diffusion in the atmosphere were discussed with special reference to such phenomena as the rainbow, the halo, the azured sky, and the twilight glow. The lecture was illustrated with lantern slides. Several members and visitors participated in the discussion. On motion of Doctor Alleman, seconded by Doctor Hoadley, a vote of thanks was extended to Doctor Humphreys. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 9, 1919.)

RESIDENT.

MR. CHARLES E. BRINLEY, President, The American Pulley Company, 4200 Wissahickon Avenue, Philadelphia, Pennsylvania.

MR. EDWIN FRANK, Mechanical Engineer, C. H. Wheeler Manufacturing Company, and for mail, 1426 Diamond Street, Philadelphia, Pennsylvania.

MR. J. HARVEY GRAVELL, Engineer, Tilghman-Brookbank Sand Blast Company, 1126 South 11th Street, Philadelphia, Pennsylvania.

PROF. WILLIAM OTIS SAWTELLE, Department of Physics, Haverford College, Haverford, Pennsylvania.

NON-RESIDENT.

MR. T. LEES BARTLESON, Chemist, Experimental Station, E. I. du Pont de Nemours Company, and for mail, 2530 West 18th Street, Wilmington, Delaware.

MR. S. C. HOLLISTER, Civil Engineer, Concrete Ship Section, Emergency Fleet Corporation, and for mail, 4420 Chestnut Street, Philadelphia, Pennsylvania.

NON-RESIDENT LIFE.

MR. HENRY FRED COLVIN, 2D, Student, 56 North Maple Avenue, East Orange, New Jersey.

ASSOCIATE.

MR. GEORGE HOLMES, Technical Journalist, 164 West 146th Street, New York City, New York.

CHANGES OF ADDRESS.

MR. ROBERT J. ANDERSON, U. S. Bureau of Mines, Experiment Station, Pittsburgh, Pennsylvania.

MR. ENRIQUE BUSTOS, Chilian Consul, Parkway Building, Philadelphia, Pennsylvania.

DR. A. S. CUSHMAN, Director, The Institute of Industrial Research, 1845 B Street, N. W., Washington, District of Columbia.

MR. THOMAS DUNCAN, Lafayette, Indiana.

MR. HENRY S. HALE, 2005 Chestnut Street, Philadelphia, Pennsylvania.

MR. G. L. KOTHNY, 2208 Rittenhouse Street, Philadelphia, Pennsylvania.

MR. W. J. MCGURTY, 3607 Forest Park Avenue, Baltimore, Maryland.

MR. W. N. RUMELY, 230 East Pearson Street, Chicago, Illinois.

MR. F. H. SHELTON, 228 South 21st Street, Philadelphia, Pennsylvania.

MR. C. S. WOOD, 315 South 15th Street, Philadelphia, Pennsylvania.

MAJOR ARTHUR W. YALE, Medical Corps, Post Surgeon, Air Service, Flying School, Rockwell Field, San Diego, California.

NECROLOGY.

Louis Edward Levy, photochemist, inventor, author and editor, died suddenly on February 16, 1919.

Mr. Levy was born in the historic town of Pilsen, Bohemia, on October 12, 1846, and came to the United States with his parents in May, 1854.

His education began in the public schools of Detroit. While attending school he obtained a position with the City Surveyor of Detroit, which gave him an insight into civil engineering and an opportunity for further study. The years 1866–67 he devoted to special courses in mathematics and physics in the University of Michigan.

He was greatly interested in meteorology and acted as observer for the United States Government at the Lake Survey Station, Detroit, from 1866 to 1873. During 1869 and 1870 he devoted much time to the study of microscopic photography. Four years later he began a series of investigations with a view to producing engravings by photochemical means. This resulted in what was known commercially as the Levytype, a process for the rapid production of half-tone illustrations for newspapers and magazines. The first American patent in this field of the graphic arts was granted to Mr. Levy in 1875. In this year the Levytype Company was established in Baltimore. After two successful years it was thought that Philadelphia would offer a still larger field for work of this character and the plant was removed to this city, where it was continued for twenty-two years.

In the meantime Mr. Levy continued his researches and experiments and introduced from time to time new apparatus and processes which greatly simplified the production of half-tone printing plates. In 1887, with his brother, Mr. Max Levy, he invented the "Half-Tone Screen"; in 1892, the "Photo-Mezzotint" process; in 1896, the "Levy Acid Blast," a new method of etching; and still more recently the "Etch-Powdering Machine."

His work as editor and publisher extended over a period of many years. *The Sunday Mercury*, an illustrated weekly, was under his management for five years, and he also directed the publication of the *Evening Herald*, of Philadelphia, for a like period. He organized the Iconographic Publishing Company, which published seven volumes of the Iconographic Encyclopedia, an elaborate series based on a well-known foreign work. In 1896 he edited and published the volume, "Cuba and the Cubans," from the Spanish, by Raimundo Cabrera, and for two years collaborated with this author in the publication of the magazine *Cuba y America*. He was author and publisher of "The Jewish Year," 1894; compiler, editor and publisher of "Wolf's American Jew as Patriot, Soldier and Citizen," 1895; author and publisher (1896) of "Business, Money and Credit." In collaboration with Mr. Hugo Bilgram he issued "The Cause of Business Depressions" in 1914.

His honors were many; he received medals, diplomas and premiums from the World's Columbian Exposition, Chicago, 1893; decoration and diploma from the Imperial Russian Photographic Society, Moscow, 1896; gold medals from the Expositions at Paris, 1900; Buffalo, 1901; St. Louis, 1904, and San Francisco, 1915. His various inventions were also recognized by The Franklin Institute, which awarded him the Elliott Cresson Medal for his Acid-Blast Method and Apparatus for Etching Metal Plates, in 1900, and the same

LOUIS E. LEVY
1846–1919

medal for his Machine for Powdering Plates for Etching, in 1904. The city of Philadelphia awarded him the John Scott Legacy Medal and Premium in 1897 for his Screens for Photo-Mechanical Engraving, upon the recommendation of the Institute.

Space prevents a detailed enumeration of the benevolent and charitable organizations and associations with which Mr. Levy was actively connected.

He became a member of The Franklin Institute on October 29, 1881, and in 1894 was appointed a member of the Committee on Library, serving continuously until the time of his death. He was three times elected Chairman. His varied knowledge of books and literature made him an invaluable member of this committee. In 1896 he was elected a member of the Committee on Science and the Arts and acted as its Chairman in 1901. Here again his knowledge of technical matters and industrial inventions and progress made him extremely useful. He was regular in his attendance, and served on many subcommittees of investigation. In 1903 he was elected a member of the Board of Managers and at the same time was appointed a member of the Committee on Publications, for the past ten years acting as its Chairman. To this Committee he undoubtedly gave his best efforts, and because of his wide experience in the engraving, printing, and publishing trades he was especially qualified to render valuable service in this important branch of the Institute's work. Since 1916 he has been one of the vice-presidents of the Institute.

At the funeral services held on February 19, Dr. Walton Clark, President of the Institute, made the following remarks:

"To be permitted to speak of Mr. Levy to a group of his friends, gathered to pay to him the last sad tribute of affection and respect, is an honor that I value highly.

"Because my acquaintance with Mr. Levy and my association with him was all in connection with the work of The Franklin Institute, it is of his devotion to that work, and of his influence upon it, and upon the men privileged to work with him, that I shall briefly speak to you.

"The words at my command are inadequate to express to you the affection and respect in which I and my associates in The Franklin Institute hold the memory of our departed friend.

"Mr. Levy served the Institute, and, through it, the public, for more than a generation. At intervals during that period of time he acted as Chairman of each of the more important committees. For the ten years just ended he was Chairman of the Publications Committee, and for this work his extended knowledge of the technique of the publisher's art, and his wonderful command of the English language preeminently prepared him. His was a large share in insuring the JOURNAL of the Institute an honored place on the shelves of the scientific libraries of the world.

"Mr. Levy's racial characteristics—his imagination rich and fertile, his passionate devotion to scientific truth, the accuracy of his mental operations, his instinct for thrift—each contributed to make his service of the highest value to the Institute and to the public it is organized to serve.

"A wonderful story of service is written against Louis Levy's name on the records of the Institute he loved so well—a record not measured by years—though, if so measured, unparalleled by any in the experience of our generation.

"Through all the serious and important labors of Mr. Levy of which I

have knowledge, he bore a cheerful, confident spirit—at times he was even playful, and often our somewhat sombre walls echoed his laughter and the laughter his humor provoked.

"It is good for us, his associates, Jew and Gentile, who have shared in the work of our honored Institution for the past twenty years, that Louis Levy has been of our number."

"The announcement of the sudden death of our esteemed friend Mr. Louis E. Levy is a great shock to me, and it will be a serious loss to The Franklin Institute as well as the community, for he was a man of broad philanthropy, who devoted himself to works for the betterment of the community and was unsparing of his time and energies in the pursuit of science, literature and the arts, that they might be applied in the best manner to the general welfare.

"He was faithful in the discharge of duty, courteous in his discussions, facile in his resources and just in his judgments, so that his opinions carried conviction and his results were accepted as sound. In the evolution of the graphic arts he was a pioneer as to economy, facility and efficiency, and in this field has added greatly to the prompt dissemination of useful knowledge by the language of form rather than words, even though 'fitly spoken.'

"His transition from the physical to the spiritual was but an illustration of the beautiful description of St. Paul where he says:

> "'We shall not all sleep but we shall be changed. In a moment, in the twinkling of an eye, at the last trump: for the trumpet shall sound, and the dead shall be raised incorruptible, and we shall be changed.' When 'Death is swallowed up in victory.'
>
> "'For as much as ye know that your labor is not in vain in the Lord.'

"Or as St. James says:

> "'For what is your life? It is even a vapour, that appeareth for a little time, and then vanisheth away.'

"But the influence of such a life as that of our friend is imperishable and has left its imprint upon the lives of many who have never had the pleasure of his acquaintance, 'and his works do follow him.' His was a painless transition and a joyful inheritance, for he was a 'Good and faithful servant,' whose memory we shall ever cherish."

LEWIS M. HAUPT.

"A life so full of work and philanthropy as that of Louis Edward Levy would seem to suggest a hunger for odd days of sport and recreation. But when Mr. Levy was not working on half-tones, or writing for technical papers, or winning medals, or on any special errand, he was at The Franklin Institute. He enjoyed its books, he liked to go over its reports, he was proud to see the long roll of savants in its lecture course.

"In the analysis of a life strong in mental achievement we must give a generous place to the general as well as the particular. We look, for instance, on William L. Marcy as an efficient Cabinet officer and as one of the hardest political fighters of his generation. It was because he was generally breast deep in the hottest line of party warfare that he loved the quiet hours of retirement over Plato, something apart from motions and debates was the tonic that steadied him. At intervals the man with a hundred business irons

in the fire goes out for a botanical ramble with a friend or passes a night in an observatory. He does not want to be an Asa Gray or a Simon Newcomb, but he yearns for the scientific atmosphere that braces him for the coming rush of orders beyond his power to supply or for the time of panic when banks go down twenty or so in a day.

"Sometimes the man who is renowned for his mastery of a specialty preserves life and reason because he is not at all times and everywhere a specialist, because he takes a general interest in something outside his chosen themes. Even the law, that proverbially jealous mistress, permits flirtations, for no year passes without its proof that a Warwick can write on French history, or a Brewster deliver lectures on colonial missions, or a John G. Johnson gather paintings from all points under heaven.

"Louis E. Levy's life was longer, broader and happier because he knew what science was doing in bridge building, in chemistry, in stellar research, in sanitation, in steel manufacture, in gas and electricity. After all, the specialist cannot forget that the wisest of Israel's kings was interested in plants, from the cedar of Lebanon to the hyssop that groweth out of the wall."

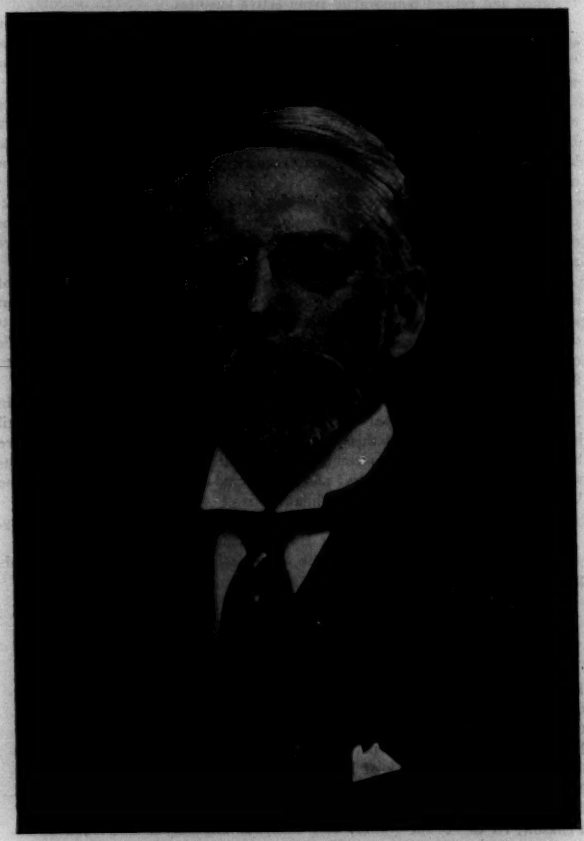
ROLAND RINGWALT.

Charles A. Brinley was born in Hartford, Conn., August 23, 1847, the son of George Brinley and Frances Ellen Terry. After attending the Hartford High School and before entering college he spent a year, chiefly in Arizona and California, as a member of the staff of the Geological Survey of California, with Clarence King and James T. Gardner, under the direction of Prof. Josiah D. Whitney.

Mr. Brinley graduated from the Sheffield Scientific School, Yale University, in 1869, and passed three more years in post-graduate work in chemistry and metallurgy in the same school.

In 1872 he came to Philadelphia, entering the employ of the Midvale Steel Company as a chemist, and two years later was made superintendent. He brought to Midvale a knowledge of metallurgical chemistry possessed by few men at that time, and by his knowledge, combined with a natural aptitude for hard work and management, he reorganized the production methods of a struggling concern and made uniformly good steel, so that when he left Midvale ten years later the company had attained a leading position in the manufacture of high-grade special steel. As superintendent of Midvale he was the first in this country to make open-hearth steel axles to meet the specifications of the Pennsylvania Railroad, the first to make open-hearth steel locomotive tires, the first to make gun forgings to meet the requirements of the United States Government and the first to roll angles, channels and I beams from rectangular steel billets. The initial four thousand tons of these shapes which came from the rolls were used in the suspended structure of the Brooklyn Bridge, and, as he says in a private memorandum written in 1909—"By the Grace of Providence they are still there." It was during the time that Mr. Brinley was superintendent at Midvale and under his supervision that the late Frederick Taylor began his work of investigation in scientific production methods.

After ten years at Midvale, Mr. Brinley was invited to become general manager of the Franklin Sugar Refinery in Philadelphia. He accepted the invitation and remained in that capacity until 1892, when the then owners sold



CHARLES A. BRINLEY
1847–1919

their interest. Although the new owners desired to retain his services, he resigned and retired temporarily from active business.

The next few years were spent in activities in relation to civic betterment and education. Two books were published, "The Voters' Handbook" and "Citizenship." He became president of the University Extension Society and was influential in establishing it upon a substantial and permanent basis.

In 1898 Mr. Brinley organized the American Pulley Company, the leading concern in the United States for the manufacture of pressed steel pulleys. He became managing director of the company soon after its organization and later its president. He continued as executive of the company until the time of his death.

As an organizer and executive he was untiring in examination and perfection of methods for efficiency in manufacture and for accurately recording the results of work done, and his mind was ever active in planning for the welfare and comfort of his employees.

Although the major part of his life was spent in the active charge of manufacturing concerns, his mind possessed the qualities of the true scientist and philosopher, and he found opportunity to interest himself in many subjects outside of purely commercial affairs. He read widely and was a sound critic of literature and art, although his abilities in these respects were known to few except his personal friends.

Mr. Brinley became a member of The Franklin Institute in 1899, and in 1903 was elected to its Board of Trustees, in which capacity he served until his death on March 2d of this year. He was a member of the Shakespeare Society of Philadelphia, a member of the Board of Directors of the Pennsylvania Institution for the Deaf and Dumb, and one of the Managers of the Western Saving Fund Society of Philadelphia.

Mr. Robert M. Dixon, 21 North Walnut Street, East Orange, New Jersey.

Mr. Jesse T. Vogdes, 127 City Hall, Philadelphia, Pennsylvania.

Mr. R. Norris Williams, 8124 St. Martin's Lane, Chestnut Hill, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

Business Digest. Vol. 5. 1918.

CHALMERS, T. W.—Production and Treatment of Vegetable Oils. 1918.

COHEN, J. B.—Organic Chemistry for Advanced Students. 3 vols. 1918.

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GUTHRIE, E. S.—The Book of Butter. 1918.

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Reader's Guide to Periodical Literature. Supplement. 6th annual. 1918.

REZELMAN, J.—Recherches sur Les Phénomènes de la Commutation. 1914.

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WILBUR, W. R.—History of the Bolt and Nut Industry in America. 1905.

GIFTS.

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Canada Department of Mines, Geological Survey, Memoir 96, Sooke and Duncan Map-Areas, Vancouver Island; Summary Reports, 1917, Parts A and F. Ottawa, 1917–1919. (From the Department.)

Clark University, Register and Thirty-first Official Announcement. Worcester, Massachusetts, 1919. (From the University.)

Columbia University, Catalogue, 1917–1918. New York City, New York, 1918. (From the University.)

General Society of Mechanics and Tradesmen, One Hundred and Thirty-third Annual Report, 1918. New York, 1919. (From the Society.)

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K. Vitterhets Historie Och Antikvitets Akademien, Fornvännen, 1916. Stockholm, 1916. (From the Academy.)

Lafayette College, General Catalogue, 1918–1919. Easton, Pennsylvania, 1919. (From the College.)

Manchester Association of Engineers, Transactions, 1917–1918. Manchester, England, 1918. (From the Association.)

Oberlin College, Annual Catalogue, 1919. Oberlin, Ohio, 1919. (From the College.)

Oil, Paint and Drug Reporter, 1918 Year Book. New York, 1919. (From the Oil, Paint and Drug Reporter, Inc.)

Pere Marquette Railway Company, Report for the Fiscal Year Ended December 31, 1918. New York, 1919. (From the Company.)

Queensland Geological Survey, Department of Mines, Publication No. 256, The Charters Towers Goldfield, by J. H. Reid. Brisbane, 1917. (From the Survey.)

R. Istituto D'Incorraggiamento di Napoli, Atti, 1916. Naples, Italy, 1917. (From the Institute.)

Swarthmore College, Catalogues, 1915–1916; 1916–1917; 1917–1918. Swarthmore, Pennsylvania, 1915–1918. (From the College.)

Sweet's Catalogue Service, Inc., Sweet's Engineering Catalogue, Fifth Annual Edition. New York, 1919. (From the Service.)

University of Pennsylvania, Catalogue, 1917–1918. Philadelphia, 1918. (From the University.)

University of the State of New York, Education Department, Annual Report, 1917, Volume I. Albany, New York, 1919. (From the University.)

Westwood Astrophysical Observatory, Occasional Scientific Papers Number 2, The Luminiferous Ether: (I) Its Relation to the Electron and to a Universal Interstellar Medium; (II) Its Relation to the Atom, by Frank W. Very. Boston, 1919. (From the Observatory.)

BOOK NOTICES.

CHEMISTRY IN OLD PHILADELPHIA. By Edgar F. Smith, University of Pennsylvania. 106 pages, 8vo. Philadelphia, J. B. Lippincott Company, 1919. Gift from the Author.

Doctor Smith tells us that the first resident of Philadelphia to make a contribution in chemistry to be published in a scientific periodical was Doctor de Normandie, who, though a practicing physician, found time to undertake real research in chemistry. His paper, which bears date of 1768, was published in the first volume of the *Transactions of the American Philosophical Society*. It discusses the composition of a sample of water from Bristol, Pa. The paper is of great importance and interest, because, Doctor Smith points out, de Normandie used the balance in his work. It has always been recognized that the balance is the characteristic instrument of the chemist, and the world has given to Lavoisier the credit of first making it the laboratory aid *par excellence*. French chemists would have us believe that chemistry was born when Lavoisier began to test his results by weight. Wurtz begins his essay on "Chemical Theory" with the words "La chimie est une science française. Elle fut fondée par Lavoisier de mémoire immortelle." This is going a little too strong, though there is no question of the value of Lavoisier's work. Doctor Smith points out, moreover, that John Rey (15— to 1645) also used the balance.

Philadelphia chemists will be greatly interested in the details that Doctor Smith gives about the early ventures into chemistry by residents of the "green countrie toun" when it was the metropolis of America, and will be grateful to him for poring over musty tomes and dusty volumes to summarize the data. One eminent chemist whom America boasts, Doctor Priestley, does not function in Philadelphia history. He was offered, indeed, a professorship of the science in this city, but he refused it, and is reported to have said that he "never saw a town he liked less." Yet this may have been a remark in a temporary petulant mood, for Doctor Smith shows that he visited Philadelphia not infrequently, and found enjoyment in some of its personal associations.

HENRY LEFFMANN.

CATALYTIC HYDROGENATION AND REDUCTION. By Edward B. Maxted, Ph.D., B.Sc., F.C.S. 101 pages, contents and index, illustrations, 16mo. Philadelphia, P. Blakiston's Son & Company, 1919. Price, $1.25 net.

There is crowded into the hundred and one pages of this book an immense amount of information on the subject of the hydrogenation of both natural and artificial substances by means of inorganic catalysts. Most of the reactions are illustrated by symbols. A brief historic introduction is given, by which we learn that the impetus to this line of research was mainly given by Sabatier and Senderens in 1899, whose papers appeared in *Comptes Rendus* from 1900 onward, and who first studied especially the activating properties of nickel. Other earlier workers are: de Wilde, Saytzeff and Kolbe, of Germany, and Cooke, of England. Many remarkable reactions, which will in time have most important practical bearings, are given. Thus Sabatier and Senderens found that by passing a mixture of carbon monoxid and hydrogen over nickel, methane is formed easily and smoothly at 250°C., and that even carbon dioxid can be substituted for the monoxid if the temperature is raised to 300°C.

The book is clearly printed on good paper and is a valuable addition to an important field of synthetic chemistry. The reviewer wishes to record his objection to the use of the phrase "*in statu nascendi*" in place of the good English "in the nascent state." There is some justification for the occasional use of a quotation in a foreign language, but scraps of Latin or French have no place as mere substitutes for English phrases just as clear and explicit. Such practices remind us of the days—now possibly, happily gone forever—when our young American students returning after a year or so of German laboratory would persist in speaking of an "Oese" and a "Schaelchen" instead of a "loop" and a "dish."

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Catalytic Hydrogenation and Reduction, by Edward B. Maxted. 104 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Company, 1919. Price, $1.25.

Michigan State Board of Health: Forty-sixth Annual Report of the Secretary for the Fiscal Year Ending June 30, 1918. 180 pages, illustrations, 8vo. Fort Wayne, Indiana, Fort Wayne Printing Company, 1919.

U. S. Department of Agriculture: Bulletin No. 753. The Use of Wood for Fuel, compiled by the Office of Forest Investigations. 40 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1919.

U. S. Bureau of Mines: Bulletin No. 174. Abstract of Current Decisions on Mines and Mining, reported from May to September, 1918, by J. W. Thompson, 138 pages, 8vo. Monthly Statement of Coal-Mine Fatalities in the United States. November, 1918. 31 pages 8vo. Technical paper 203. Labor Saving at Limestone Quarries, by Oliver Bowles. 26 pages, 8vo. Technical paper 207. Combustion Experiments with North Dakota Lignite, by Henry Kreisinger, C. E. Augustine and W. C. Harpster. 44 pages, illustrations, plates, 8vo. Technical paper 221. Saving Steam in Industrial Heating Systems. Reprint of Engineering Bulletin No. 6 prepared by the United States Fuel Administration in collaboration with the Bureau of Mines. 14 pages, illustrations, 8vo. Washington, Government Printing Office, 1919.

Remedial Railroad Legislation, 1919: Testimony Before Senate Committee on Interstate Commerce and Statements Bearing on the Return of the Railroads of the United States to Private Management and Operation, and on Remedial Legislation to Accompany such Return, as Suggested by the Association of Railway Executives, January, 1919. Edited by Robert S. Binkerd, Assistant to the Chairman. 279 pages, tables, 8vo. New York and Washington, Association of Railway Executives, 1919.

Supplement to Remedial Railroad Legislation, 1919: Containing Testimony Before the Senate Committee on Interstate Commerce, by Mr. J. Kruttschnitt, President, Southern Pacific Company, and a Statement Read Before the Same Committee by Mr. Daniel E. Willard, President of the Baltimore and Ohio Railroad Company. 98 pages, 8vo. New York and Washington, Association of Railway Executives, 1919.

American Telephone and Telegraph Company: Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1918. 60 pages, 8vo. New York, 1919.

Transportation: An Address by Maj. Gen. William M. Black, Chief of Engineers, U. S. Army. Delivered Before the Fourteenth Convention of the National Rivers and Harbors Congress, Washington, D. C., February 5, 1919. 16 pages, 8vo. Washington, National Rivers and Harbors Congress, 1919.

Production of Garnet in 1918. ANON. (*U. S. Geological Survey Press Bulletin,* No. 405, April, 1919).—There are many kinds of garnet, and the most widely known kinds are the least abundant. Garnets that can be cut into the well-known handsome and sometimes highly prized gems are rare. On the other hand, some garnets are in many places so abundant that they are frequently spoken of by mineralogists as "ordinary garnet." Some varieties of ordinary garnet, like many other common things of unattractive appearance, are far more useful than the rare and beautiful varieties, and probably the total value of the common garnet annually consumed greatly exceeds the value of all the gems. Certain varieties of common garnet are used as abrasive materials—that is, they are used for cutting and polishing by grinding or rubbing. Abrasive garnet is used chiefly in the form of so-called sandpaper and cloth. Strange to say, in the United States at the present time sandpaper is never made with sand; most commonly it is made with crushed quartz, and some of it is made with garnet, emery, corundum, and artificial abrasives. The common quartz paper is generally called sandpaper; the others go by the names garnet paper, emery paper, corundum paper, etc.

According to statistics compiled by Frank J. Katz, of the United States Geological Survey, Department of the Interior, the mine output of abrasive garnet in the United States in 1918 was 4127 short tons; and the quantity of milled garnet marketed was 4600 tons, valued at $242,401. Producers of garnet reported stocks in hand at the end of the year amounting to 2030 tons.

During 1918 the price of abrasive garnet produced by quarry and mill operators ranged from $25 to $60 a short ton and averaged $52.70. The mine ouptut was somewhat smaller in 1918 than in previous years, in spite of a heavy demand for garnet; this decrease was due largely to difficulty in holding an adequate supply of skilled labor at the quarries and mills. The garnet produced came chiefly from Warren County, N. Y.; small amounts were contributed also by Merrimack County, N. H., and Clay County, N. C.

CURRENT TOPICS.

Rare Elements as Paint Pigments. H. A. GARDNER. (*Educational Bureau, Paint Manufacturers' Association of the United States,* Circular No. 62, April, 1919.)—Many of the rarer elements that heretofore have had but little industrial application received much consideration during the war-time period. It is probably safe to state that many of them will be used as the basis of preparations destined to become of great importance in the arts. Their possibilities as pigment bases, for instance, for several years have engaged the writer's interest. Among the more obscure or not commonly known metals that he has experimented with are molybdenum, cerium lanthanum, selenium, thorium, titanium, tungsten, uranium, vanadium, zirconium, beryllium and radium. Nearly all of the above metals, in the form of their respective insoluble compounds, have a high refractive index and consequently produce, when ground with oil, very opaque mixtures having a hiding power comparable with lead and zinc pigments.

From the standpoint of war-time usage, radium pigments have been of the greatest interest, substantial quantities having been used for aircraft instruments and other paraphernalia of modern warfare. The radium may be applied as a salt to an active or sympathetic base having real pigment properties, such as zinc sulphide. This activated pigment is mixed with a thin, clear varnish that acts as binder. Only small amounts of radium salts are required in such paints to produce energetic vibrations that send out active radiations in the form of a soft greenish glow. These paints have almost entirely replaced the old luminous calcium sulphide paints which, although comparatively low in price, depend upon absorption of energy from sunlight. The only substitute for radium is mesothorium, an element found in monazite sand that is mined in certain of our southern states. Its longevity is not as great as that of radium.

Selenium, an element analogous in some of its properties to sulphur, which is obtained during the smelting and refining of copper, has had but little industrial application. The writer has prepared several most interesting pigments from it (the selenites of lead and borium, for instance) which are very white and of fine grain. Their exceptionally high refractive index gives them intense opacity. Other pigments of a closely related nature may be produced from beryllium, an element found as a silicate or aluminate in several eastern states. The oxide and similar products of zirconium have a very high degree of whiteness, opacity

and permanence. From titanium, an element which is widely distributed, many most interesting compounds have been produced, and it is highly probable that some day they will be used to a great extent as pigments where great opacity, permanence and other closely related physical properties are desired. Among the more common elements from which white pigments may be made are arsenic, antimony, bismuth and tin. The toxic nature of some of these compounds and their high price as compared with lead and zinc pigments have limited or prevented their use.

Metal Powders as Pigments. H. A. GARDNER. (*Educational Bureau, Scientific Section, Paint Manufacturers' Association of the United States,* Circular No. 61, April, 1919.)—Finely divided metal powders have specific uses as pigments. Zinc powder (zinc dust), for instance, has been employed to some extent as a pigment, and for many years has formed a substantial part of the antifouling and anticorrosive ships' bottoms paints used by the Navy Department; for instnace, a paint made of finely divided zinc powder suspended in a heavy bodied drying oil, a spar varnish, or a lacquer could be used as a "liquid galvanizing." Great fineness of the zinc powder is the chief requisite and the paint should contain at least 90 per cent. of metallic zinc of such fineness that 96 per cent. shall pass through a 300-mesh screen. When applied to a bare iron surface, there would be a water-proof film containing a metal that would protect the iron from corrosion. Aluminum, lead, copper, iron and other metals in powdered form have found special applications as surface coatings.

When metal powders are employed as primer paints, those metals should preferably be used that have a higher solution tension than that to which it is applied. If two metals are placed in contact in the presence of water a primary battery is formed, and galvanic action ensues. The electropositive metal will go into solution and the electronegative metal will be unacted upon. In the order of their solution tendencies, the metals commonly used are: aluminum, zinc, iron, nickel, lead, copper, tin and antimony. Any of these metals when placed in contact in the presence of water with another metal lower in the series will tend to protect the latter metal from corrosion. Zinc is the only commercially available metal of moderate price, and applicable as a coating, that is higher in the series than iron. This metal is therefore theoretically ideal to use as a protective coating on iron surface when applied in the form of galvanizing. The film of zinc, even when abraded, will have a marked protective influence upon the adjacent areas of bare metal.

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